

CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

Editor

Frances L. Parker

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME XI, PART 2, APRIL, 1960

205. THE TAXONOMIC POSITIONS
OF THE GENERA *BOLDIA* VAN BELLEN, 1946,
AND *ANOMALINELLA* CUSHMAN, 1927

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ABSTRACT

The type species of *Boldia* van Bellen, 1946, was originally designated as *Rotalina lobata* Terquem. The specimens from the Montian of Bunde, Holland, upon which van Bellen based his genus were wrongly identified by him. They are referable to *Boldia madrugensis* Cushman and Bermúdez which should, therefore, be considered the type species of *Boldia* (C. D. Z. N., 1953, pp. 68, 69). A second species from the same Montian material, questionably called *Rotalia obesa* Terquem by van Bellen, is referable to *Boldia cubensis* Cushman and Bermúdez.

Anomalinella rostrata (Brady) differs from the *Planulina* group of *Almaena*, *Kelyphistoma*, *Planulinella* only in having embracing chambers on both sides. The so-called supplementary apertures near the margin, even in the last-formed chamber, are closed by porous plates, as is the case in all the other groups mentioned. Comparison with the type species of *Planulina*, *P. ariminensis* d'Orbigny, leads to the conclusion that the whole group is a very homogenous one and must be closely related to the type species of *Planulina*. A simple emendation of the genus *Planulina* enables us to place all these forms in that genus, thus greatly simplifying our system.

BOLDIA VAN BELLEN, 1946

Introduction

In 1946, van Bellen described a formation (in reality, two formations, not recognized as such, are to be found in the material from borings near Bunde, South Limburg, Holland) which he attributed erroneously to the Middle Eocene (Lutetian). The careful comparison of his samples with the abundant material from localities in the vicinity shows that in reality they are typical Montian, the lower ones identical with the Tuffeau de Ciply near Mons, the upper with the Calcaire Grossier de Mons, also near Mons, Belgium.

From his material, van Bellen (1946a, p. 86, pl. 13, figs. 13-16) described "*Terquemia lobata* (Terquem)." In studying Terquem's (1882, p. 63, pl. 4, fig. 1) description and figure, he could easily be misled because the figure is poor. The new one given by Le Calvez (1952, p. 50, pl. 4, fig. 4) of the only specimen known of this Lutetian form, clearly shows that van Bellen did not have Terquem's species but something quite different.

Later, van Bellen (1946b, p. 122) changed the name *Terquemia* to *Boldia* since the former name was a homonym.

In van Bellen's material there are two species which are referable to species from the Cuban Paleocene, *Boldia madrugensis* Cushman and Bermúdez (1948a, pl. 12, figs. 4-6) and *B. cubensis* Cushman and Ber-

múdez (1948a, pl. 11, figs. 15, 16). Since van Bellen's "*Rotalina lobata* Terquem" is not referable to that species but to *Boldia madrugensis* this should be considered the type species of *Boldia* (C.D.Z.N., pp. 68, 69, Para. 128).

Van den Bold (1946, p. 124, pl. 18, fig. 6) described *B. vandersluisi* from the Paleocene of Guatemala but his species differs from van Bellen's and, therefore, *B. madrugensis* is the correct name for the type species.

Van Bellen's figure of "*Rotalina lobata*" is not good since apparently he used poor material from the lower part of the borings, the Tuffeau de Ciply; much better material from near the top of the borings is to be found among his samples. The species referred by him to ?*Rotalia obesa* Terquem (van Bellen, 1946a, p. 63, pl. 8, figs. 14-16) are, in reality, *Boldia cubensis* Cushman and Bermúdez.

Description of *Boldia madrugensis*
Cushman and Bermúdez

In the adult test, the dorsal side shows the last-formed whorl of chambers slightly inflated, with depressed radial sutures, coarse pores and the center covered by somewhat irregular secondary chalk material. The periphery is broad, slightly rounded to flattened, often with acute edges at both sides. This periphery also shows distinct pores, at least on the part towards the dorsal side. On the ventral side each chamber shows distinct striae running from the periphery towards the center; on each chamber these striae run somewhat obliquely, so that the striae of a chamber are distinct from those of the adjacent chambers. In the center these striae from the older chambers fuse into small ribs which run over the center of the test.

In younger tests, the striae of the different chambers appear to be the ornamentation of large tena which reach the center and cover the umbilical region; in more adult tests these tena fuse in the middle and are obscured by the strigilate surface.

In the youngest tests observed, near the peripheral suture of the last-formed chamber there is an irregular row of rounded pores (situated on short necks) which forms the aperture; in more adult tests this row seems more disarranged and irregular openings result. In the youngest tests, on the dorsal side the chambers can be seen right up to the initial ones, with thickened sutures between them. These sutures, in more adult



TEXT FIGURES 1-8

Figs. 1-7, *Boldia madrugensis* Cushman and Bermúdez. 1, $\times 27$; a, dorsal side; b, apertural face; c, ventral side. 2, $\times 27$; a, dorsal side; b, apertural face; c, ventral side. 3, $\times 57$; transverse section showing the individual in the position in which it would have been attached to the substrate, with the ventral side above; the distinct thickened tena on the ventral side, covering most of the umbilical hollow, are very conspicuous. 4, $\times 57$; young specimen; a, dorsal side; b, apertural face with the apertural openings on short necks; c, ventral side. 5, $\times 57$; young specimen; a, ventral side showing the tena not yet fusing over the umbilical hollow; b, apertural face showing the peculiar apertures. 6, $\times 57$; young specimen with the apertural face slightly reversed so that the necks on which the apertures are situated can be seen. 7, $\times 57$; very young specimen.

Fig. 8, *Boldia cubensis* Cushman and Bermúdez. $\times 27$; a, dorsal side; b, apertural face; c, ventral side. Figs. 1, 4-7 are from Mine Shaft Maurits III, Calcaire de Mons; fig. 1, 178.50 m.; figs. 4-7, 177.50 m.

Figs. 2, 3, 8 are from one of the type localities of van Bellen (1946); Drill Hole Bunde II, 25-26 m.; Calcaire de Mons.

tests, fuse into the irregularly ornamented central part of the dorsal side.

Sections show that the whole wall is very thick, and that the tena of the later chambers, especially, form many lamellae which cause the strigilate surface on the ventral side. But, in all sections studied, the tena in reality do not fuse together completely and thus umbilical openings always remain on the ventral side. The horizontal sections show that the septal walls are double.

Discussion

All these characteristics point to the family Gavellinellidae. In that family the genus *Stensioina* most closely resembles the genus *Boldia*. In *Stensioina* also the tests often have thick walls and the tena in more advanced species thicken in the region of the umbilicus and may cover the lateral region entirely (*Stensioina pommerana* Brotzen, *S. altissima* Hofker, *S. esnehenensis* Nakkady). In *S. esnehenensis* pores are found also on the dorsal side, which feature is lacking in the geologically older species of this genus. In *Boldia madrugensis*

pores are found on both the ventral and dorsal sides. In *Stensioina esnehenensis*, the geologically youngest species known, the aperture is not a sutural slit but an irregular row of pores, as is the case in *Boldia madrugensis*. For this reason, it seems best to consider *Boldia* a descendant of *Stensioina*. *Stensioina* was considered by the author (Hofker, 1957) to be an attached genus; *Boldia* likewise seems to have been attached by its dorsal side to algae.

Cushman (1948) placed *Boldia* in his family Anomalinellidae, but the ventral tena and open umbilicus, though covered by the later tena, clearly show that it does not belong to this group.

Bermúdez (1952) placed the genus in the vicinity of *Heronallenia* Chapman and Parr, but that genus, in reality, belongs to the *Buliminella* group; he also considers that it is related to *Discopulvinulina* Hofker and to other members of his subfamily "Discorbisinae" (Discorbinae). Since, however, most of these genera typically have either a protoforamen only, or both a protoforamen and deuteroforamen, none of them can

be allied to *Boldia*. On the other hand, the group of genera included in the Gavelinellidae fit this genus perfectly.

Since the formation studied by van Bellen is not Middle Eocene but Lower Paleocene (Montian), and since all other described species of this genus were found in the Paleocene, the genus *Boldia* seems to be an excellent Paleocene marker.

The only specimen known of *Rotalina lobata* Terquem cannot belong to this genus as supposed by van Bellen and Le Calvez. This species is a *species incerta* since it has not been refound in the many samples of the Lutetian of the Paris Basin either by Le Calvez or the author, and the original figure and description do not adequately define the form.

The other species found in the Montian of Holland and Belgium, described by van Bellen as ?*Rotalia obesa* Terquem, should be referred to *Boldia cubensis* Cushman and Bermúdez since, according to Le Calvez (1949, p. 9), in Terquem's collection there is only one very poorly preserved specimen bearing that name. This specimen cannot be redescribed nor could Le Calvez find any specimens in her material. Terquem's name should, therefore, be considered a *nomen dubium*.

ANOMALINELLA CUSHMAN, 1927

Discussion

Cushman (1927, p. 93) has established the genus *Anomalinella* for *Cibicides*-like forms which are nearly planispiral and almost involute on both sides, having, what he called, a supplementary aperture just below the peripheral margin. The type species is *Truncatulina rostrata* Brady. Cushman's (1948, p. 335) description of the genus is as follows:

"Test in the early stages trochoid, adult nearly planispiral; chambers almost entirely involute; wall calcareous, coarsely perforate; aperture ventral between the periphery and the umbilical area with a supplementary aperture just below the peripheral margin, elongate and parallel to the axis of coiling.—Miocene to Recent."

There seems to be a single species, the genotype; records of species from the Miocene all show the typical features of this form. The author has studied a large number of specimens from near Sorong, New Guinea, where the species is abundant in many samples from coral reefs. The two sides of the tests are in most cases clearly distinguishable, one with a very small, central, opaque chalky mass with the chambers nearly reaching the center, the other with less involute chambers. On the latter side the so-called supplementary apertures are visible. The former side, where the supplementary apertures are not visible and the chambers reach the center, is, as transverse sections show, the ventral one. For the first sets of chambers overlap on this side and not on the other, dorsal one. More-

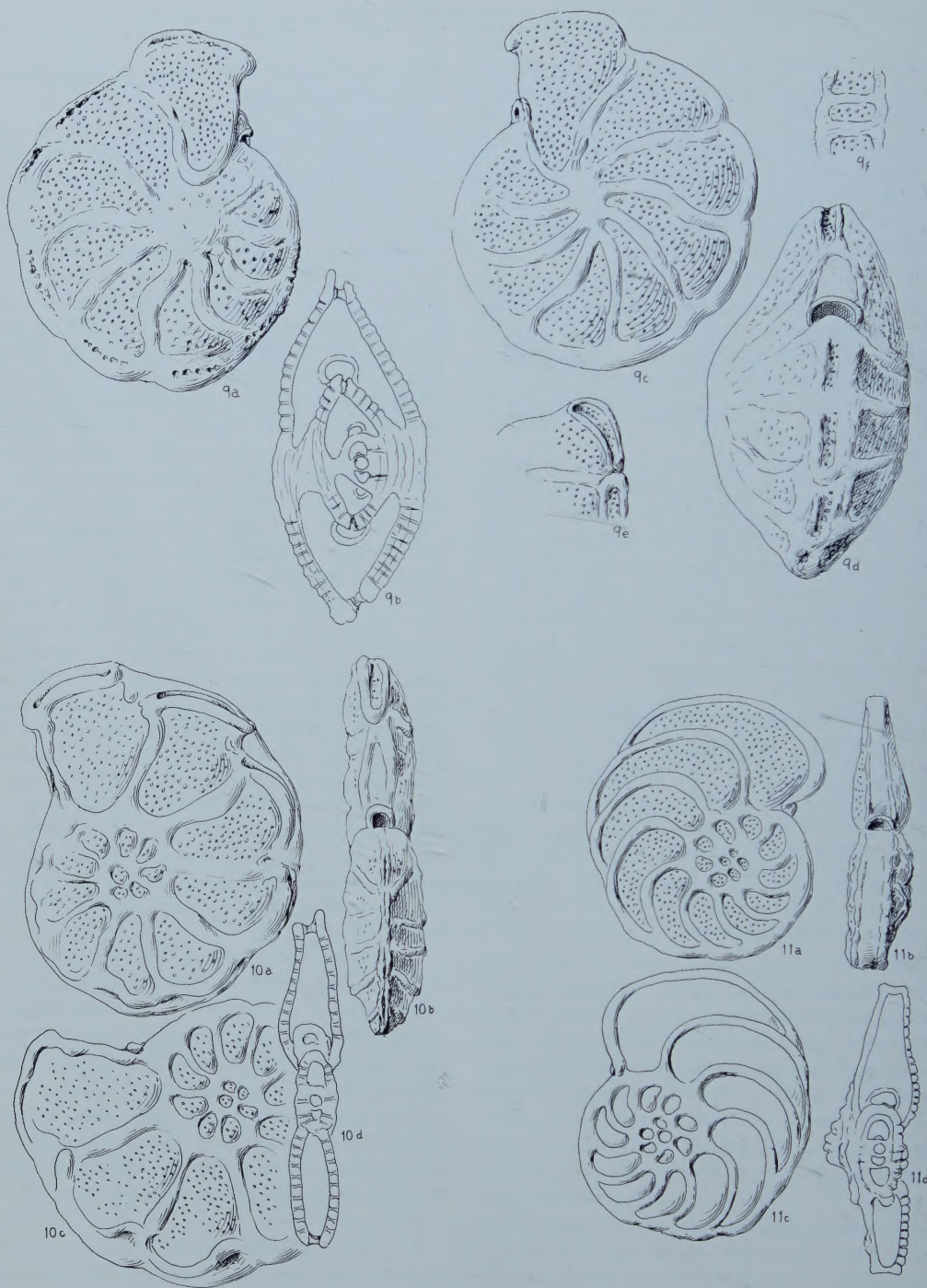
over, the marginal septal apertures always overlap towards this ventral side.

The last-formed chamber shows a striking resemblance to those of *Planulina osnabrugensis* Roemer and the other forms which are clearly related to that species as the author (Hofker, 1952) has shown previously. There the author showed that all the genera, *Alamaena*, *Kelyphistoma*, *Planulinella*, (and we may now add *Queralina*) belong to the same genus, of which the type must be the oldest described species, *Planulina osnabrugensis* Roemer. In both the forms, *P. osnabrugensis* and *Anomalinella rostrata*, the last-formed chamber shows the same raised margin, nearly poreless triangular face, and the lip above the marginal (not ventral), rounded aperture. The only difference is that its sides, in *A. rostrata*, more completely overlap the sides of the test than is the case in *Planulina osnabrugensis*. Special attention was given to the so-called supplementary openings. As was shown in the discussion of the *P. osnabrugensis* group, these openings, which had also been described as open apertures, in reality are closed by a thin, porous plate. Fortunately the author found some well preserved specimens of *Anomalinella rostrata* in which the last-formed marginal "aperture" was also covered by a thin plate having the same coarse pores as are found in the walls of that species. Moreover, in all specimens, even in those where the thin plate has been destroyed, the supplementary apertures of the earlier chambers are all closed by these porous plates, since in these older chambers this plate has thickened. In transverse sections the location of the plates, which in reality are only the marginal part of the wall surrounded by the thickened border, often is clearly visible in the former whorls also.

So, these open, supplementary apertures do not exist any more than they do in the *Planulina osnabrugensis* group. Often in the last-formed chamber, however, the marginal wall is so thin, being only a pseudochitinous layer with pores, that it is broken away and suggests an open foramen.

Thus, *Anomalinella rostrata* differs from the species of the *Planulina osnabrugensis* group only in the more overlapping chambers, a feature found in many species of the *Cibicides*-*Planulina* group, and not to be considered a generic one.

After the publication of the paper on *Planulina osnabrugensis*, very fine specimens of *P. alavensis* Palmer were obtained from Dr. Bermúdez. Drawings, including a section, of that species are given here for comparison showing that it also belongs to the *P. osnabrugensis* group. All these species, which have been referred to different genera (*Planulina*, *Planulinella*, *Pseudoplanulinella*, *Kelyphistoma* and *Almaena*), belong without any doubt to a somewhat specialized group of *Planulina* in which the often recurring flattened margin (*P. ariminensis* d'Orbigny) in some cases



TEXT FIGURES 9-11

Fig. 9, *Anomalinaella rostrata* Brady. $\times 57$. Recent, Sorong, New Guinea. a, dorsal side; b, transverse section showing septal foramina and the so-called marginal apertures closed by porous plates; c, ventral side; d, apertural face; e, two of the porous, marginal plates of a young specimen; f, porous plates slightly ground down to the inner side of the plates.

Fig. 10, *Planulina alavensis* Palmer. $\times 57$. Upper part of middle Oligocene, Tarava, Habana Province, Cuba (Bermúdez sta. 595). a, dorsal side; b, apertural face; c, ventral side; d, transverse section showing the porous plates of the margin and a septal foramen.

Fig. 11, *Planulina ariminensis* d'Orbigny. $\times 57$. Beach at Rimini, Italy. a, ventral side; b, apertural face; c, poreless dorsal side (attached side); d, transverse section showing some septal foramina.

is placed slightly asymmetrically and is bordered by more or less thick walls. In the paper on *P. osnabrugensis* I suggested that all these species should be included in the genus *Planulina*. I showed that in some species or varieties of this group the chambers are more involute on the ventral side than on the dorsal; this is also the case in "*Anomalina*" *rostrata*. The sections given in that paper show that in many cases the so-called supplementary apertures are slightly bent towards the dorsal side (a fact emphasized by Sigal, 1949, also); this is also the case in "*A.*" *rostrata* where contrarily to what Cushman says ("with a supplementary aperture just below the peripheral margin") this "supplementary" aperture always is found slightly bent towards the dorsal side of the test.

So, there is not the slightest doubt that all these forms: *Planulina osnabrugensis* Roemer, *P. alavensis* Palmer, *P. altocostata* Ten Dam, *Kelyphistoma ampulolocolata* Keyzer, *K. siphoninaeformis* Sigal, *Almaena taurica* Samoilova, *Planulinella escornebovensis* Sigal, and *Queraltina colomi* Marie are allied closely to *Anomalina*, so closely that they cannot be referred to different genera. They all belong to the *Planulina* group, flattened and planispirally coiled *Parelloides*, (see Text fig. 3 in which is shown the type species, *P. ariminensis*).

If we prefer to gather all these species and forms into a separate genus, we must, according to the Rules of Zoological Nomenclature, place them in Cushman's genus *Anomalina* but this is not believed to be necessary since they all show only very slight differences from *Planulina ariminensis*. There is no need for a separate genus because they are forms of *Planulina* in which the margin shows two pronounced borders, a feature found also in *P. ariminensis*.

To prove this point not only figures of "*Anomalina*" *rostrata* are given but also of *Planulina alavensis* and *Planulina ariminensis*, from the type locality at Rimini, Italy. The figures of *Planulina alavensis* clearly show that this species belongs to my *Planulina osnabrugensis* group; the difference from that species, *P. costata*, etc., is so small that only slight specific differences might lead to differing specific names. The figures of "*Anomalina*" *rostrata* clearly show that here we have a species differing from those of the *P. osnabrugensis* group only in the involute character of the chambers; consequently the umbilical areas are filled up with chalky material. *P. ariminensis* from Rimini in section shows a close resemblance to sections of specimens of the *P. osnabrugensis* group. Yet there are differences, for in *P. ariminensis* only one side has pores whereas the other is poreless; the very highly developed sutural chalk ridges on the dorsal side also occur in some species of the *Almaena* group but both "*Almaena*" and "*Anomalina*" have pores on both sides of the test. However, many species of *Parelloides* show a great deal of variation in this respect, some

having pores on both sides, others only on the dorsal side. It may be that in *Planulina ariminensis* the porous side is the ventral one since the marginal septal foramina curve towards this side. The poreless side is the attached one. Many species of *Planulina* from the Tertiary have pores on both sides of the test so that this feature is of no real generic importance for this genus, as far as we know now. Another difference is the lack of pores in the flat margin of *P. ariminensis*. This is due to the fact that in the Oligocene several species of the "*Almaena*" group occur showing pores in the margin, which is possibly of generic significance. In that case a different generic name for these forms would be adequate; otherwise, all the generic names proposed by authors after Cushman, 1927, are valueless according to the Rules of Zoological Nomenclature, since his *Anomalina* could be readily adopted for all those species by slightly emending Cushman's diagnosis. As a matter of fact, several species of the *Planulina* (*Almaena*) *osnabrugensis* group already show a tendency to become slightly involute.

Thus, if it seems preferable to give a separate name to all those species of *Planulina* in which a flattened margin gives rise to a so-called supplementary aperture, which is, however, closed by a porous plate, this name must be *Anomalina*. The diagnosis of the genus then would be:

Anomalina Cushman, 1927, emend. Hofker

Test in the early stages slightly trochoid, adult nearly planispiral; chambers in some cases not embracing former coils, in others almost entirely involute; wall calcareous, always coarsely perforate; aperture almost totally peripheral, usually with a thickened border, in a poreless apertural face having distinctly raised borders; periphery truncate, with raised borders on both sides and a porous plate between; last-formed chambers always with the marginal part more or less raised above the marginal surface. Eocene to Recent.

Species belonging to this genus would be: *Anomalina colomi* (Marie) (*Queraltina*) Upper Eocene; *A. osnabrugensis* (Roemer) (*Planulina alticostata* Ten Dam, *Planulinella escornebovensis* Sigal, *Almaena taurica* Samoilova); *A. siphonaeformis* (Sigal) (*Pseudoplanulinella hieroglyphica* Sigal), both from the Oligocene; *A. alavensis* (Palmer), upper Oligocene; *A. rostrata* (Brady), Miocene to Recent.

In my opinion all these forms could be placed in a slightly emended diagnosis of *Planulina*; for convenience, one could place them in a subgenus *Anomalina*.

The importance of this study lies in the conclusion that four or five genera, established recently by several authors, are synonyms of a single genus established by Cushman 1927, or even an older one, *Planulina* d'Orbigny. Moreover, it proves that in the Anomalinidae (*Parelloidinae*?) no real supplementary apertures exist; supplementary apertures are found mostly in connection with toothplates which do not occur in this group.

In addition, it has been shown that during the development of a genus (*Planulina*) a nearly planispiral form may eventually develop involute chambers. This phenomenon is encountered in many rotaliform groups; *Discopulvinulina* develops embracing chambers on the dorsal side (*Hanzawaia*); *Parelloides* shows this development also; in *Gavelinella*, too, involute forms occur in the late Cretaceous (*Cibicidoides*); primitive *Peneroplidae* are evolute, but in the course of development several genera of that family form involute chambers as well. Previously I have shown that *Hanzawaia* is merely an involute *Discopulvinulina*; in the same way *Anomalinella* s. s. is an involute *Planulina*. It is matter of taste whether or not to separate such groups, but surely it is not very efficient to separate them into different genera since intermediate forms always occur. If one did so, one would also have to separate evolute *Peneroplis bradyi* from involute *P. pertusus*. The number of genera would be enlarged considerably without any practical result.

There is, in this respect, a very important question regarding the Rules of Zoological Nomenclature. For, when dealing with a group of species obviously belonging together, common sense would reason that the tests showing the most characteristic and primitive characters should be regarded as the typical representatives of the genus; consequently those tests should give the genus its name. Yet in several cases generic names have been given to those species of the group which show advanced characteristics rather than the typical features. In such a case the Rules demand that the older name be given to the genus, with the result that the type species is not the typical one for the genus. This, for example, is the case with *Hanzawaia* which is an older name than *Discopulvinulina*. *Hanzawaia* is relatively rare, whereas *Discopulvinulina* is the common form, including also those aberrant forms like *Hanzawaia*. Thus, it would be much better and more efficient to uphold the name *Discopulvinulina* and to use *Hanzawaia* as a subgeneric name within that genus. Moreover, it can be said that *Hanzawaia* is not a monophyletic genus, whereas *Discopulvinulina* is. The same can be said for *Colomia* which is a specialized form of *Conorboides*.

It would be much better to give all those forms of the "*Almaena*" and *Anomalinella* group the original name, *Planulina* with perhaps *Anomalinella* as a subgeneric specification. For although *Anomalinella* is an older name than *Almaena*, etc. it has been given to a

form which is obviously derived from those Oligocene forms. The use of *Anomalinella* as a generic name for the whole group will once more lead to the absurdity that a derived and not typical form gives the generic name to the whole group, in which many typical forms occur. The group as a whole is not *Anomalina*-like, but *Planulina*-like.

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206. SOME PRIMARY TYPES OF SPECIES
BELONGING TO THE SUPERFAMILY GLOBIGERINACEAE
— A FURTHER TAXONOMIC NOTE

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Following upon the paper published in vol. XI, part II, pp. 1-41, 1960, Cushman Foundation Forum. Res., Contr., on "Some Primary Types of Species Belonging to the Superfamily Globigerinaceae," R. V. Melville, Assistant Secretary to the International Commission on Zoological Nomenclature, has kindly pointed out to us that the authorship of some taxa, originating from, and credited by us to, Alcide d'Orbigny, but which were first validly published by C. Fornasini, should be reconsidered. As the author of a species should be he who provides it with the necessary description, definition or indication, and as it is logical that authorship and date should generally go together, the following corrections to the above paper should therefore be made:

p. 10, col. 2: *Globigerina depressa* should be credited to Fornasini, 1903 (*ex d'Orbigny*);

p. 16, col. 1: *G. punctulata* should be credited to Fornasini, 1899 (*ex d'Orbigny*);

p. 19, col. 1: *G. rotundata* should be credited to Fornasini, 1898 (*ex d'Orbigny*);

p. 30, col. 2: *Rotalia limbata* should be credited to Fornasini, 1902 (*ex d'Orbigny*); and

p. 33, col. 1: *Rotalia nitida* should be credited to Fornasini, 1906 (*ex d'Orbigny*).

None of the conclusions reached by us (*op. cit.*) are affected in any way; the lectotypes selected for the above taxonomic units as credited to d'Orbigny maintain their status when the taxa are credited to Fornasini, as d'Orbigny's specimens must clearly stand as syntypic. There appears to be no difference in these cases, compared to that of *Rotalia menardii* Parker, Jones and Brady, 1865 (*ex d'Orbigny*). *Globigerina punctulata* Fornasini, 1899 (*ex d'Orbigny*), therefore becomes an objective junior synonym of *G. punctulata* Deshayes 1832.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME XI, PART 2, APRIL, 1960

207. NEW OBSERVATIONS ON *PELOSPHAERA CORNUTA*

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ABSTRACT

1. Apart from the test of *Pelospheera cornuta* the animal itself is characterized by having a relatively thick organic wall which is modified at one part in the form of an oral region with a definite mouth. In many respects this region is remarkably similar to that known in *Gromia oviformis*.

2. When characters of the test alone are considered the inclusion of *P. cornuta* in the family Astrorhizidae may appear to be justified, whereas, if characters of the protoplasmic body are taken into account a closer affinity to the Saccamminidae is indicated.

INTRODUCTION

The author has recently had the opportunity of examining twenty alcohol-preserved specimens of *Pelospheera cornuta* Heron-Allen and Earland, 1932, some of which were undamaged and contained the protoplasmic body. Whereas the test (Pl. 9, fig. 1) has been adequately described and figured by Heron-Allen and Earland (1932) and Earland (1933, 1934) there is apparently no account of the animal itself. This short communication is primarily concerned with noting and discussing the significance of the organic wall and the specialised oral region of the animal.

MATERIAL

The specimens were collected on a cruise of R.R.S. Discovery in 1926 from a depth of 136 metres at Station 140, between Stromness Harbour and Larsen Point, South Georgia, (from 54° 02' S, 36° 38' W to 54° 11' 30" S, 36° 29' W). This locality is within the area from which Heron-Allen and Earland (1932) first described the species and, with the exception of six specimens from the Graham Land area (Earland, 1934), *P. cornuta* has, to the author's knowledge, not been recorded elsewhere.

PRESENT SYSTEMATIC POSITION

When *P. cornuta* was originally described the co-authors considered it to be closely allied to *Psammospheera* and included it in the sub-family Saccammininae of the family Astrorhizidae. Later, however, Earland (1934) found specimens which possessed flexible tubes extending from the test to a length equal to the test-diameter. This is a characteristic of *Astrorhiza limicola*, in which long flexible tubes are developed as extensions to the more rigid basal parts of the arms of the test. The similarity in this respect between *P. cornuta* and *A. limicola* led Earland to transfer the former from the sub-family Saccammininae to the Astrorhizinae, that is from the family Saccamminidae to the Astrorhizidae according to Cushman (1948).

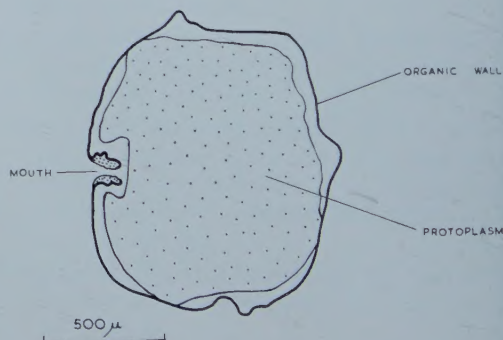
No change of opinion nor systematic position has occurred since.

OBSERVATIONS

The only previous comment on the animal, apart from the test, is that of Heron-Allen and Earland (1932) who refer to an "orange coloured sphere almost filling the central cavity, which is probably the protoplasmic body in a chitinous envelope."

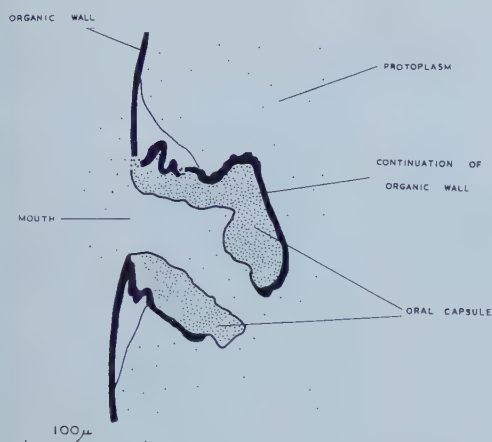
When the friable test is broken open the spheroidal protoplasmic body is seen to occupy approximately two-thirds of the volume of the test-interior. Considering that the specimens are alcohol-preserved it is not unreasonable to assume that in the living state the animal almost fills the test-cavity. For purposes of further examination the animals have been fully dehydrated, embedded by Peterfi's celloidin paraffin method (Pantin, 1946) and sections cut at a thickness of 8 μ . Subsequent staining was with Mayer's Haemalum and eosin, or Heidenhain's Azan, both according to Pantin (1946), or with a 0.01 per cent aqueous solution of toluidine blue according to Pearse (1953). It is from sections of *P. cornuta* prepared and stained in this way that the following observations have been made.

1. The protoplasm is enclosed by an organic wall which is apparently imperforate and approximately 10 μ thick. Although alcohol-fixation is most unsuitable for good preservation of this structure, it may be noted that there are signs of the wall being laminated.



TEXT FIGURE 1

Outline drawing made using a Zeiss drawing attachment of a transverse section of *P. cornuta*. The space between the protoplasm and the organic wall in both this figure and figure 2 is due to the greater shrinkage after fixation of the protoplasm as compared with the organic wall.



TEXT FIGURE 2

Outline drawing made using a Zeiss drawing attachment of a transverse section of *P. cornuta* through the oral region to show the relationships of the organic wall, and the oral capsule.

2. There is a specialisation of the wall at one point in the form of an oral region with a definite mouth (Pl. 9, fig. 2; text figs. 1, 2). This oral region, characterised by the mouth and the gel-like 'oral capsule', is remarkably similar both structurally and in its affinity for stains to the oral region described by Hedley (1960) in *Gromia oviformis* Dujardin, 1835.

In addition to these two observations it may be noted that the animals are literally packed with diatoms, almost exclusively of a single species belonging to the genus *Thalassiosira* (Pl. 9, figs. 2, 3), and that all the animals which have been examined are multinucleate with nuclei approximately 70 μ diameter (Pl. 9, fig. 3).

COMMENT

If the characters of the animal itself are taken into consideration it would appear that *P. cornuta* is closely related to the Saccamminidae for in both *Saccammina sphaerica* (teste Rhumbler, 1894a; and author's own observations) and *P. cornuta* the protoplasm is enclosed by a relatively thick organic wall, and in both cases there is a single well-defined mouth and oral region. So far as is known at present *Astrorhiza* possesses neither of these structures and it is presumed that in *A. limicola* the pseudopodia develop from any region of the protoplasm, whereas in *S. sphaerica* and *P. cornuta* the pseudopodia presumably protrude through the mouth in a way similar to that known in *Gromia* or *Allogromia*.

It is very tempting, but nevertheless rather premature, to note the newly-observed characters of the protoplasmic body and to explore further their possible significance in relation to family relationships. Before this can be attempted we must have as a basis further

information of a structural and biological nature about the families and animals being discussed. Any discussion on the significance of the oral region of *P. cornuta*, for example, ought to take into account similar structures in other foraminifera such as the "stomostyle" of *Rhyncosaccus immigrans* (Rhumbler, 1894b) or the "pharynx" of *Iridia serialis* (Le Calvez, 1936) and the structures referred to in the literature as "oral apparatus," "apertural region" or mouth with the aim of determining to what extent are they homologous or analogous structures. The following list of foraminifera (*Gromia oviformis* being included, but not necessarily recognised as a foraminifer) includes those forms for which there exists a reasonably good figure of an oral structure and which the present author considers, after examination of the published figures, are in some ways similar to that found in *P. cornuta*. It must be emphasised, however, that detailed descriptions of most of these structures do not exist and until they do any further discussion is of doubtful value.

Reference

<i>Gromia oviformis</i>	Arnold, 1952
	Hedley, 1960
<i>Allogromia gracilis</i>	de Saedeleer, 1934
<i>Allogromia lagenoides</i>	teste Cushman, 1948
<i>Allogromia laticollaris</i>	Arnold, 1948
<i>Rhyncosaccus immigrans</i>	Rhumbler, 1894b
<i>Iridia lucida</i>	Le Calvez, 1936
<i>Iridia serialis</i>	Le Calvez, 1935
<i>Saccammina sphaerica</i>	Rhumbler, 1894a

All the animals listed above have an organisation where the protoplasm is enclosed by a thick organic wall, which in the case of *Allogromia* sp. and *Gromia* is the test itself, and where access to the exterior beyond the wall is through a mouth or oral region. Such a structural organisation is not so far known in any member of the Astrorhizidae, and its common occurrence in members of the Allogromiidae and Saccamminidae and in *P. cornuta* warrants further study of a comparative nature when these forms are available.

It has already been noted that the presence of flexible tubes extending from the test led Earland to consider *P. cornuta* to be a member of the Astrorhizidae. It ought to be remembered, however, that tubes of this sort are known to be occasionally present in the tests of *S. sphaerica*. Both Rhumbler (1894a) and Lücke (1910) have referred to them as "die Pseudopodialröhren" and consider them to be "similar" to the freely moveable distal terminations of the arms of *Astrorhiza limicola*. Whether this superficial resemblance has any systematic importance has yet to be proven through a comparative study of the behaviour, structure and biology of the animals concerned.

In the meantime the author is inclined to look upon *Pelosphaera cornuta* as a member of the Saccamminidae rather than of the Astrorhizidae.

ACKNOWLEDGMENT

I would like to thank my colleague Dr. C. G. Adams for discussing the content of this paper and for reading the manuscript.

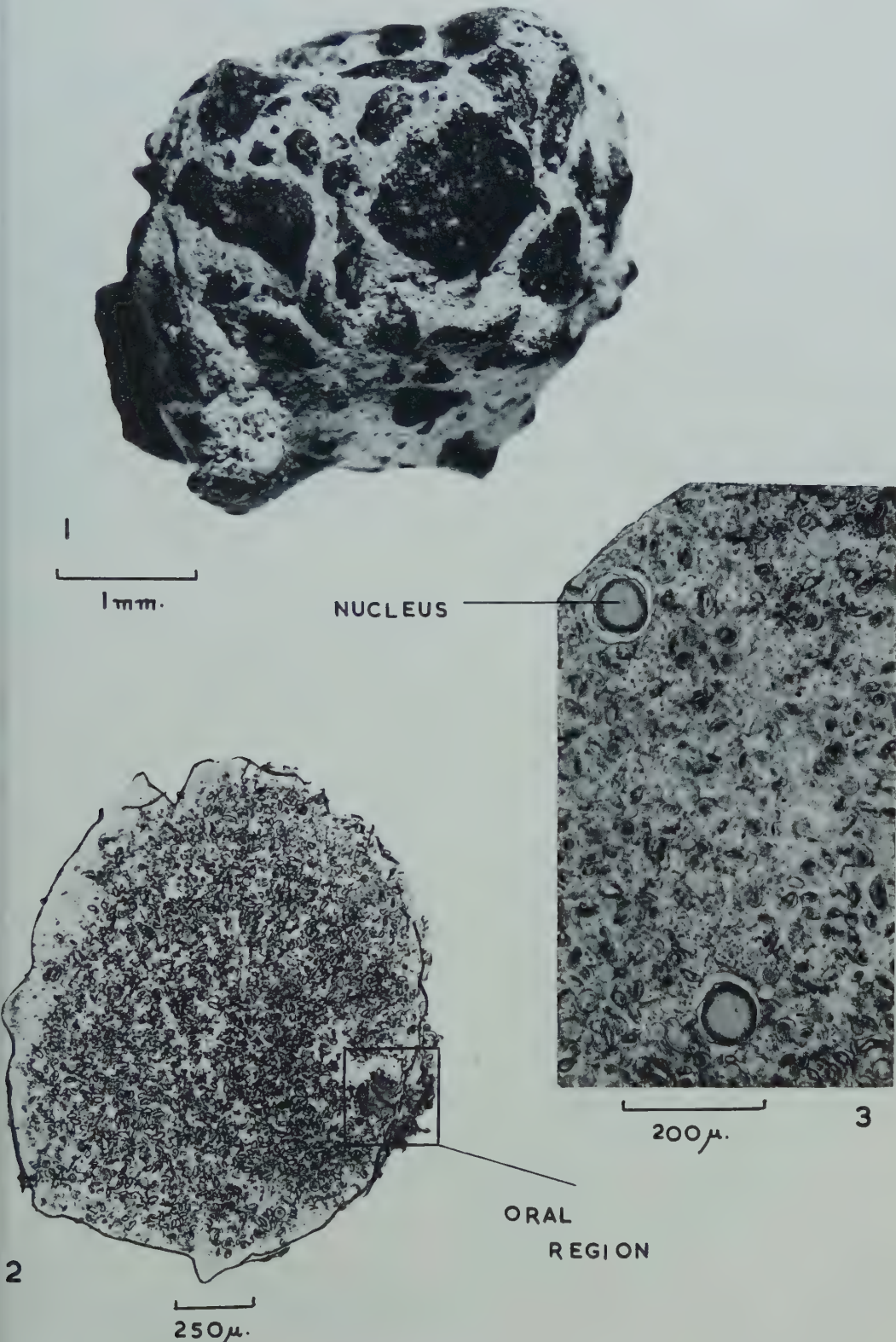
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EXPLANATION OF PLATE 9

FIGS.

	PAGE
1. The test of <i>Pelosphaera cornuta</i> Heron-Allen and Earland	54
2. A transverse section of <i>P. cornuta</i> through the oral region. 8μ. Stained with toluidine blue	55
3. Part of a section of <i>P. cornuta</i> showing two nuclei and the diatoms mentioned in the text. 8μ. Stained with Heidenhain's Azan.	55



Hedley: *Pelosphaera cornuta*

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME XI, PART 2, APRIL, 1960

208. REVISION OF *HELICOSTEGINA*, *HELICOLEPIDINA*
AND *LEPIDOCYCLINA* (*POLYLEPIDINA*)*

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ABSTRACT

The genera *Helicostegina* and *Helicolepidina* and the subgenus *Polylepidina* of the genus *Lepidocyclus* are reviewed. New illustrations are given of many of the species discussed. The species *Helicostegina gyralis* Barker and Grimsdale is a synonym of *H. dimorpha* Barker and Grimsdale. The species previously known as *Helicolepidina polygyralis* Barker, *Helicolepidina paucispira* Barker and Grimsdale and *Helicostegina soldadensis* Grimsdale are combined and assigned to the genus *Helicostegina* under the name *H. polygyralis* (Barker). Two species are recognized in the genus *Helicolepidina*, *H. spiralis* Tobler from the upper middle Eocene and *H. nortoni* Vaughan from the upper Eocene. The genus *Eulinderina* Barker and Grimsdale is a synonym of *Lepidocyclus* (*Polylepidina*). A brief statement on the probable evolution of the lepidocyclines and these other genera based on this revision is presented.

INTRODUCTION

Many of the genera and species of American Tertiary larger Foraminifera have been interpreted incorrectly (Cole, 1958b, p. 261). This report is a continuation of studies to attempt to clarify certain erroneous concepts which have been established by an analysis of the subgenus *Polylepidina* of the genus *Lepidocyclus* and the genera *Helicostegina* and *Helicolepidina*.

Ever since Vaughan (1924, p. 807) erected the subgenus *Polylepidina*, there has been confusion regarding the diagnostic characters of this subgenus. Numerous species have been assigned incorrectly to *Polylepidina* and one genus *Eulinderina* Barker and Grimsdale (1936, p. 237) has been based on specimens which are obviously *Lepidocyclus* (*Polylepidina*) *antillea* Cushman (= *L. (P.) chiapasensis* Vaughan), the type of *Polylepidina*.

The genus *Helicostegina* Barker and Grimsdale (1936, p. 233) has been misinterpreted by Tan (1936, p. 243), and Barker and Grimsdale (1936, p. 243) assigned species to *Helicolepidina* which should have been referred to the genus *Helicostegina*.

The genus *Helicolepidina* has two species, the type species, *H. spiralis*, which seemingly is restricted to the upper middle Eocene and *H. nortoni* Vaughan (1936, p. 248) which seemingly occurs only in the upper Eocene. Previously, these two species which are similar in their internal structures have not been separated by most workers.

Most of the specimens on which this report is based have been in my possession for many years, but recently I received from John B. Saunders excellent specimens of *Helicostegina soldadensis* Grimsdale [1941, in Vaughan and Cole, p. 86 = *Helicostegina polygyralis* (Barker)] from the upper Eocene of Trinidad.

These specimens from locality 4 (see: locality descriptions) came from the type locality in Trinidad of the *Globorotalia cerroazulensis* zone (Bolli, 1957, p. 160). This zone was named the *Globorotalia cocoaensis* zone, but *G. cerroazulensis* (Cole, 2 April 1928) has priority over *G. cocoaensis* (Cushman, 1 September 1928).

In addition to *Helicostegina polygyralis* this sample contained the following species of larger Foraminifera:

- Operculina floridensis* (Heilprin)
- trinitatensis* (Nuttall)
- Lepidocyclus* (*Pliolepidina*) *pustulosa*
H. Douvillé
(normal and abnormal)
- (*Nephrolepidina*) *chaperi*
Lemoine and R. Douvillé
- Helicolepidina nortoni* Vaughan
- Asterocyclus asterisca* (Guppy)
- Pseudophragmina* (*Proporocyclus*) *flintensis*
(Cushman).

Recently, Grimsdale (1959) published a short but stimulating paper in which he discussed as an interim review his concepts of the evolutionary development of American species referred to the genus *Lepidocyclus*. In an appendix (p. 24) he summarizes completely the generic and subgeneric names applied to the lepidocyclines and related genera and in a second appendix (p. 27) he lists and discusses "Species-groups in the American Lepidocyclinidae."

However, the confusion regarding the internal structures and relationships of certain genera and species is evident. He (Grimsdale, 1959, p. 17) wrote: "The connecting links between *Helicolepidinoides gyralis* and *Helicolepidina polygyralis* remain to be discovered, but it seems almost certain that *Helicolepidina paucispira* was a direct offshoot from *Helicolepidinoides soldadensis*. . . ." An attempt will be made to demonstrate that *Helicolepidina paucispira* and *Helicostegina soldadensis* are synonyms of *Helicolepidina polygyralis* and that *H. polygyralis* should be referred to the genus *Helicostegina*.

* The cost of the printed plates was supplied by the William F. E. Gurley Foundation for paleontology of Cornell University. Grateful acknowledgment is made to Hans G. Kugler and John B. Saunders for their courtesy in supplying critical specimens from Trinidad, British West Indies.

LOCALITIES

St. Bartholomew, French West Indies

Loc. 1 - U. S. Geol. Survey no. 6897. Conglomerate and sandstone below upper limestone, Anse Ecaille side of point between Anse Ecaille and Anse Lizard; T. W. Vaughan, collector.

Loc. 2 - From a section of approximately 45 m. thickness composed of cross-bedded massive *Lithothamnium* and foraminiferal limestones with two bands of cross-bedded, conglomeratic volcanic tuffs at the promontory separating Anse des Lézards and Anse des Cayes on the north coast of the island; A. Senn, collector.

2a - S. B. 12. Marly tuff, 0.2 m. thick with abundant larger Foraminifera forming a transition zone between the lower horizon of cross-bedded tuffs and the overlying limestones.

2b - S. B. 13; S. B. 14. Small bands of brown marly tuff with abundant larger Foraminifera, alternating with the massive limestone beds, directly overlying the lower horizon of cross-bedded tuffs.

2c - S. B. 16. Sandy limestone with abundant larger Foraminifera, interstratified with the massive top limestones overlying the upper horizon of cross-bedded tuffs (southeast end of promontory).

Trinidad, British West Indies

Loc. 3 - Vistabella quarry, San Fernando; H. G. Kugler, collector.

Loc. 4 - K. R. 25684. Steep bank on east (waiting rooms) side of San Fernando Railway Station (coordinates N: 237060 links; E: 356425 links); dark grey-brown calcareous silt; J. B. Saunders, collector.

Panama

Loc. 5 - W. 125. Quebrancha syncline; road to Nuevo San Juan, 1.3 miles southwest of junction with Transisthmian Highway; fairly soft limestone; T. F. Thompson and W. P. Woodring, collectors.

Florida

Loc. 6 - W. 453. City of Tallahassee water well in Lafayette Park, Leon County; Section 30, Town-

ship 1 N. Range 1 E., about 4100 feet northeast of the post-office at a depth of 407 feet (cutting sample).

COMMENTS ON THE GENUS *HELICOSTEGINA*
BARKER AND GRIMSDALE, 1936

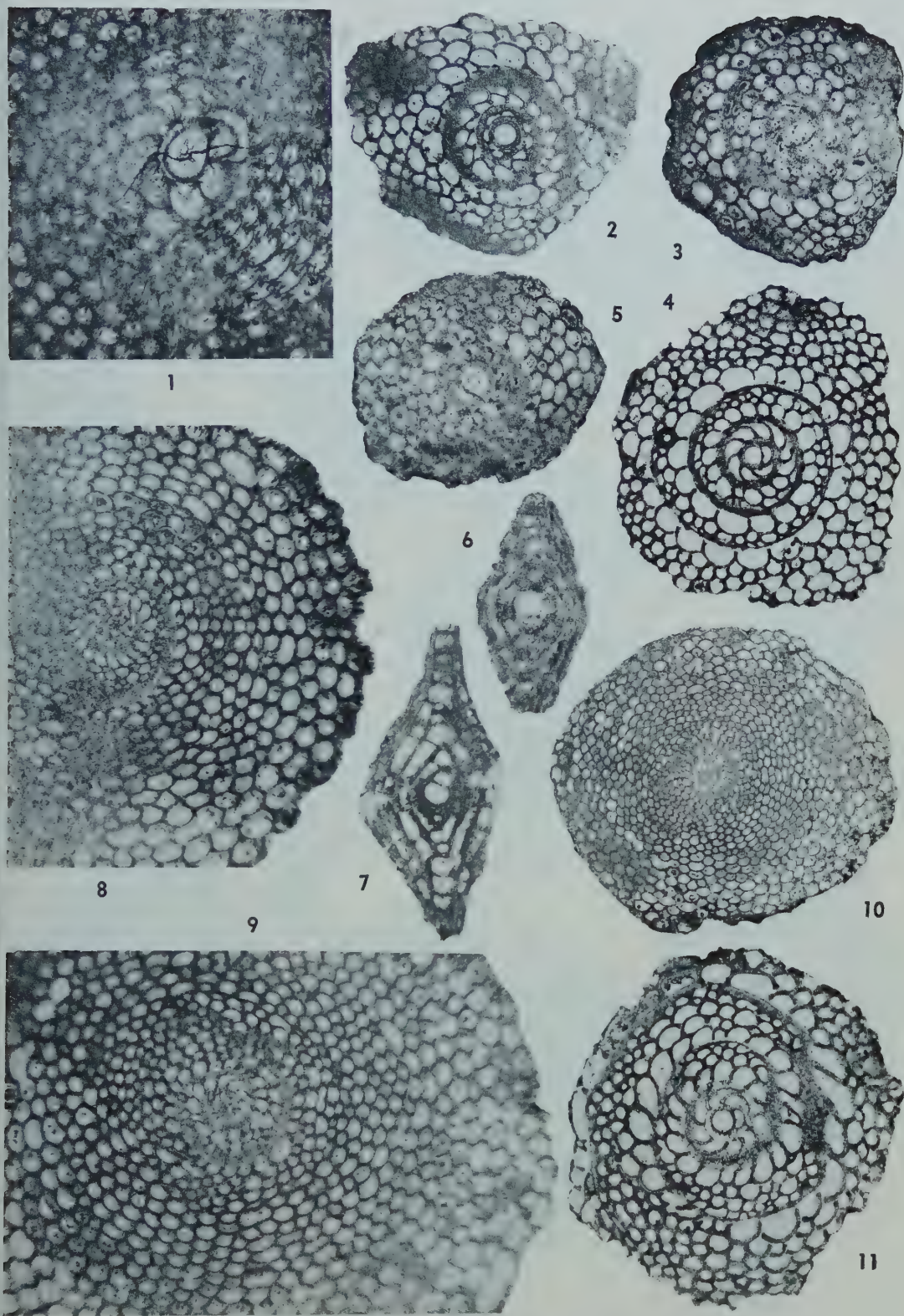
This genus (Barker and Grimsdale, 1936, p. 233) was based upon specimens from the Guayabal formation (middle Eocene) of the Tampico Embayment Area, Mexico. The type species is *Helicostegina dimorpha* Barker and Grimsdale (1936, p. 235). The authors (1936, p. 234) characterize this genus as follows: "Test multichambered, the earliest chambers coiled in an involute trochoid spire, the chambers of the later coils subdividing ventrally into two or more subsidiary chambers or chamberlets. In the more primitive species (*H. gyralis*, n. sp.) the chamberlets are restricted to the ventral region of the test, upon which they form a continuous layer but in the more specialized form, represented by the genotype, this layer of chamberlets extends peripherally as a more or less undulating compressed flange one cell thick, almost surrounding the early spiral portion which forms concentric umbones on the dorsal and ventral surface of the test."

Two species were described, the type of the genus *H. dimorpha*, and *H. gyralis* Barker and Grimsdale (1936, p. 236). *H. gyralis* differed from *H. dimorpha*, according to the authors, "in the possession of a greater number of whorls in the spire, and in the absence of a flange" (p. 237). However, if the specimen illustrated by Barker and Grimsdale (1936, pl. 34, fig. 6) as *H. gyralis* is compared with their figure of *H. dimorpha* (1936, pl. 34, fig. 9), it will be observed that the two specimens are identical. Cole and Gravell (1952, p. 713) have concluded that it was doubtful if these two species could be separated. This study confirms their supposition that *H. gyralis* is a synonym of *H. dimorpha*.

Tan (1936, p. 243) referred *Helicostegina dimorpha* to the genus *Eulinderina* Barker and Grimsdale (1936, p. 237) and at the same time (Tan, 1936, p. 254) erected the genus *Helicolepidinoides* with *Helicostegina gyralis* as the type species. Inasmuch as it can be demonstrated that *H. dimorpha* and *H. gyralis* represent only one species, and that *Eulinderina* is a syno-

EXPLANATION OF PLATE 10

FIGS.	PAGE
1. <i>Lepidocyclina</i> (<i>Polylepidina</i>) <i>antillea</i> Cushman	60
1. Central part of an equatorial section, $\times 40$, of a megalospheric specimen; locality 2a.	
2-11. <i>Helicostegina polygyralis</i> (Barker)	59
2-5, 11. Equatorial sections, $\times 40$, of megalospheric specimens; 2, 4, 11, locality 4; 3, 5, locality 6.	
6, 7. Vertical sections, $\times 40$, of megalospheric specimens; 6, locality 6; 7, locality 4.	
8, 9. Part of equatorial sections, $\times 40$, of microspheric specimens to show the initial coil; locality 6.	
10. Equatorial section, $\times 20$, of the same specimen illustrated as figure 9.	



Cole: *Helicostegina*, *Helicolepidina*, *Lepidocyclina* (*Polylepidina*)



Cole: *Helicostegina*, *Helicolepidina*, *Lepidocyclina* (*Polylepidina*)

nym of *Lepidocyclina* (*Polylepidina*), the generic name *Helicostegina* is valid with *H. dimorpha*, the type species.

COMMENTS ON THE SPECIES

HELICOSTEGINA POLYGYRALIS (BARKER)

This species was described by Barker (1932, p. 309) and was based upon specimens obtained from Ecuador from "a lens of coarse grit on the sea coast near Ancon which is believed to be near the top of the Socorro series. . . ." (p. 305). He assigned this species to the genus *Helicolepidina* Tobler.

Later, Barker (1934, p. 347) discussed this species in more detail and gave additional illustrations. Barker and Grimsdale (1936, p. 241) mentioned this species and gave three additional illustrations.

Barker and Grimsdale (1936, p. 243) described from the upper Eocene of the Tampico Embayment Area, Mexico, a new species which they called *Helicolepidina paucispira*. Later, Grimsdale (in Vaughan and Cole, 1941, p. 86) described from the upper Eocene of Trinidad a species which he named *Helicostegina soldadensis*. At the same time Grimsdale identified for Vaughan and Cole (1941, p. 76) a single equatorial section of a specimen from the upper Eocene of Trinidad as *Helicolepidina paucispira* Barker and Grimsdale.

Cole (1945, p. 46) found in the upper Eocene of a shallow well in Florida megalospheric and microspheric specimens which he referred to *Helicolepidina paucispira* Barker and Grimsdale.

Finally, Tan (1936, p. 254) separated *Helicolepidina paucispira* from the genus *Helicolepidina* and made it the type of a new genus *Helicocyclina*. This new genus has been accepted commonly as a synonym of *Helicolepidina* (Grimsdale, 1959, p. 25).

If the illustrations which have been published of "*Helicolepidina*" *polygyralis*, "*Helicolepidina*" *paucispira* and *Helicostegina soldadensis* are arranged in sequence and carefully compared, it is obvious that only one species is represented. Moreover, all of these specimens have the fundamental pattern which characterizes the genus *Helicostegina*. Therefore, "*Helicolepidina*" *paucispira* and *Helicostegina soldadensis* are synonyms of "*Helicolepidina*" *polygyralis*, the first name used, and "*H.*" *polygyralis* must be transferred to the genus *Helicostegina*.

The length of the whorls of spiral chambers is extremely variable in these specimens. The illustrations of the type specimens (Barker and Grimsdale, 1936, figs. 1, 3, pl. 36) of *H. paucispira* show a short whorl similar to the ones (FIG. 5, PL. 10 and fig. 4, pl. 1, Cole, 1945) of the specimens from Florida originally identified as *H. paucispira*. Moreover, in these specimens the whorls of spiral chambers do not extend to the periphery. However, other specimens (FIG. 3, PL. 10) from the same population have a longer whorl of spiral chambers which does reach the periphery. The specimen (FIG. 2, PL. 10) of *H. soldadensis* is an exact duplicate of *H. paucispira* (FIG. 3, PL. 10). Another specimen (FIG. 12, PL. 11) from Trinidad is virtually identical with the type illustration (Barker, 1932, fig. 5, pl. 22).

The vertical sections of all of these specimens, microspheric (FIGS. 1, 9, 10, PL. 11) as well as megalospheric (FIGS. 2-5, 7, 8, PL. 11), show a distinct trochoid coil around the embryonic chambers. These vertical sections are similar to those of *Helicostegina dimorpha* (compare FIG. 2, PL. 11 with fig. 6, pl. 32, Barker and Grimsdale, 1936) except the flange is more developed in *Helicostegina polygyralis*. The vertical sections of *H. paucispira* (figs. 4-6, pl. 33, Barker and Grimsdale, 1936) are identical with those of *H. polygyralis* (figs. 7, 9, 10, pl. 47, Barker, 1934). The vertical section (FIG. 8, PL. 11) of *H. soldadensis* is nearly a duplicate of *H. paucispira* (fig. 5, pl. 33, Barker and Grimsdale, 1936).

The thickness of the walls of the trochoid coil is variable from thin (FIG. 4, PL. 11) to thick (FIGS. 3, 8, PL. 11). This is a characteristic of individual specimens and is not a specific character. It is probable that the thickness of the walls is controlled by some ecological factor (Cole, 1958a, p. 191).

The vertical sections of *Helicostegina* are markedly different from those of *Helicolepidina* (FIG. 11, PL. 11) in that the equatorial zone in *Helicolepidina* is continuous to the embryonic chambers, whereas this zone in *Helicostegina* is not. The only discontinuity in the equatorial layer in *Helicolepidina* is at the place where the spiral whorl of chambers intersects the equatorial layer (see: FIG. 11, PL. 11, upper part about midway between the embryonic chambers and the periphery).

EXPLANATION OF PLATE 11

FIGS.	PAGE
1-5, 7-10, 12. <i>Helicostegina polygyralis</i> (Barker)	59
1, 9, 10. Vertical sections, 1, 10, $\times 20$, 9, $\times 40$, of microspheric specimens; locality 6.	
2-5, 7, 8. Vertical sections, $\times 40$, of megalospheric individuals; 2-4, 8, locality 4; 5, 7, locality 6.	
12. Equatorial section, $\times 40$, of a megalospheric specimen; locality 3.	
6, 13. <i>Lepidocyclina</i> (<i>Polylepidina</i>) <i>antillea</i> Cushman	60
6, 13. Vertical sections, $\times 20$, of microspheric specimens; 6, locality 2b; 13, locality 2c.	
11. <i>Helicolepidina nortoni</i> Vaughan	60
Vertical section, $\times 40$, of a megalospheric specimen; locality 3.	

COMMENTS ON THE GENUS *HELICOLEPIDINA* TOBLER, 1922

Helicolepidina spiralis Tobler (1922, p. 380) is based upon a specimen (Tobler, 1922, fig. 1) in which the spiral whorl of the equatorial zone is continuous from the second embryonic chamber to the periphery of the test. This spiral whorl nearly surrounds the embryonic chambers and is generated from the first periembrionic chamber.

This specimen is from the Rio San Pedro, Bolivar District, State of Zulia, Venezuela. Brönnimann (1944, figs. 16-19, pl. 3) has given some excellent illustrations of the central part of other specimens from this same locality. Raadshooven (1951, p. 7) demonstrated that these specimens came from beds which are upper middle Eocene in age.

The upper Eocene specimens from Trinidad, Panama and elsewhere in the Caribbean region which have been assigned traditionally to *Helicolepidina spiralis* have two initial periembrionic chambers (FIGS. 3, 6, PL. 13), one on each side of the dividing wall between the initial and second embryonic chamber. The spiral whorl (FIG. 3, PL. 13) may be generated from one of these initial periembrionic chambers, but it does not nearly surround the embryonic chambers as it does in the specimens from the upper middle Eocene of Venezuela. Moreover, in most specimens from the upper Eocene (FIGS. 6, 7, PL. 13) the spiral whorl is separated from the embryonic chambers by a zone of small equatorial chambers.

Brönnimann (1944, p. 22) recognized these differences and proposed that the specimens from Trinidad be separated from those in Venezuela (typical *H. spiralis*) under the varietal designation *Helicolepidina spiralis trinitatis*.

However, Vaughan (1936, p. 248) had described under the name *Helicolepidina nortoni* specimens from a well in Louisiana which are identical with specimens from Trinidad named by Brönnimann *H. spiralis trinitatis*.

Although Cole (1952, p. 30) demonstrated that *H. nortoni* and the upper Eocene specimens which were assigned to *H. spiralis* were identical, he did not recognize that it might be possible to separate the upper middle Eocene specimens from those found in the upper Eocene.

Therefore, it is proposed that two species of *Helicolepidina* based on the differences in the spiral whorl be recognized: *Helicolepidina spiralis* Tobler from the upper middle Eocene and *Helicolepidina nortoni* Vaughan from the upper Eocene.

The illustrations given by Raadshooven (1951, p. 9, 11) under the name *Helicolepidina spiralis* represent two species. His text figures A-D (p. 11) and figs. 3, 4, pl. 3 from the upper middle Eocene are *Helicolepidina spiralis*, whereas his text figures E-G (p. 11) and figs. 5, 6, pl. 3 are *Helicolepidina nortoni*.

Helicolepidina spiralis occurs in the upper middle Eocene of western Venezuela and in northwestern Peru (Todd and Barker, 1932, p. 532). In Peru it is associated with *Pseudophragmina* (*Proporocyclina*) *clarki* (Cushman) [= *Discocyclina restinensis* Todd and Barker] (Cole, 1958c, p. 419) and specimens which were identified as *Lepidocyclina vichayalensis* Rutten. However, Todd and Barker's illustrations (1932, pl. 40, figs. 5, 6) of *L. vichayalensis* also represent *Helicolepidina spiralis*. But, *Lepidocyclina vichayalensis* Rutten (1928, p. 945) was based on specimens of *Helicolepidina nortoni* Vaughan.

All of the upper Eocene specimens from Trinidad, Panama, Florida, and other geographic areas formerly included with *Helicolepidina spiralis* are without doubt *H. nortoni*.

COMMENTS ON THE SPECIES *LEPIDOCYCLINA* (*POLYLEPIDINA*) *ANTILLEA* CUSHMAN

Cole (1944, p. 57) has illustrated and discussed this species. In that article he gave many of the synonyms of this species, all of which seemingly were assigned correctly with the exception of *Lepidocyclina* (*Pliolepidina*) *kinlossensis* Vaughan (1928, p. 287) which is a synonym of *Lepidocyclina* (*Pliolepidina*) *macdonaldi* Cushman (Cole, 1956, Table 2).

However, certain other species must be added to the synonymy of *L. (Polylepidina) antillea*. These follow:

Eulinderina guayabalensis (Nuttall) Barker and Grimsdale, 1936, p. 238, pl. 32, figs. 8, 9; pl. 34, figs. 8, 10, 11; pl. 37, fig. 4.

Eulinderina guayabalensis regularis Barker and Grimsdale, 1936, p. 238, pl. 30, figs. 7, 9; pl. 32, figs. 10, 11; pl. 35, figs. 4, 5; pl. 37, fig. 5.

Eulinderina semiradiata Barker and Grimsdale, 1936, p. 238, pl. 30, figs. 10-12; pl. 32, figs. 15-17; pl. 35, figs. 1-3; pl. 37, fig. 1.

Other species, formerly classified as *Polylepidina*, although they were not assigned to the species *L. (P.) antillea*, are obviously incorrectly placed subgenerically. An example is *Polylepidina discoidalis* Barker and Grimsdale (1936, p. 241) which is a synonym of *Lepidocyclina* (*Pliolepidina*) *proteiformis* (Vaughan).

Eulinderina was separated from *Polylepidina* by Barker and Grimsdale (1936, p. 237) by "... the possession of a well-marked trochoid spiral surrounding the nucleocoach, the chambers of the spire being connected by apertures of the *Amphistegina* type, with anteriorly directed inner lips."

The late Dr. Alfred Senn had made extensive collections in St. Bartholomew among which were many specimens of *Lepidocyclina* (*Polylepidina*) *antillea* Cushman. These specimens are as near topotype specimens as can be obtained at the present time.

Several of these specimens (FIGS. 1, 3, 6, PL. 12; FIG. 5, PL. 13) have the trochoid spire and apertures which

supposedly characterize *Eulinderina*. Inasmuch as there is no difference between *Eulinderina* and *Lepidocyclus* (*Polylepidina*), *Eulinderina* must be a synonym of *L. (Polylepidina)*.

Megalospheric specimens of *L. (Polylepidina) antillea* from a single population have considerable variations in the number of perie embryonic chambers, the size of these chambers, the length of the perie embryonic coil and the thickness of the revolving wall adjacent to the embryonic chambers. These differences in part are the result of the position of the particular equatorial section, but mainly they are produced by individual differences in growth.

The specimen (FIG. 1, PL. 12) has 8 perie embryonic chambers which form a nearly complete whorl around the embryonic chambers, whereas the specimen (FIG. 6, PL. 12) has 4 perie embryonic chambers which extend only about halfway around the embryonic chambers. The specimen (FIG. 5, PL. 13) has a thick perie embryonic revolving wall, another specimen (FIG. 1, PL. 12) has a moderately thick perie embryonic revolving wall and a third specimen (FIG. 6, PL. 12) has a thin revolving wall. This same diversity is shown by other specimens (see: Cole, 1944, figs. 1-7, pl. 10; figs. 3, 4, pl. 12).

The illustration of "*Eulinderina guayabalensis*" given by Barker and Grimsdale (1936, fig. 10, pl. 34) should be compared with FIGURE 5, PLATE 13, and their figure 9, plate 32 should be compared with FIGURE 2, PLATE 12. The megalospheric specimens of "*Eulinderina semiradiata*" Barker and Grimsdale (1936, figs. 1, 3, pl. 35) should be compared with FIGURE 7, PLATE 12. The microspheric specimens of "*Eulinderina semiradiata*" Barker and Grimsdale (1936, fig. 17, pl. 32; fig. 2, pl. 35) should be compared with FIGURE 13, PLATE 11 and FIGURE 8, PLATE 12.

All of the specimens here referred to *Lepidocyclus* (*Polylepidina*) *antillea* characteristically have the chamber walls of the equatorial chambers as viewed in vertical section with straight walls extending across almost the entire width of the equatorial layer. At each end these walls bend sharply proximally before they fuse with the floor and roof of the equatorial layer.

In the description of *Lepidocyclus* (*Polylepidina*) *gardnerae* Cole (1929, p. 60, fig. 3, pl. 7) (= *L. (P.) antillea*), Cole remarked upon the absence of well developed lateral chambers in certain specimens. These "vacuolar" lateral chambers of *L. (P.) antillea* are the same as those described for "*Eulinderina semiradiata*" Barker and Grimsdale (1936, p. 239).

KEYS TO THE SPECIES OF *HELICOSTEGINA*, *HELICOLEPIDINA* AND *LEPIDOCYCLINA* (*POLYLEPIDINA*)

In order to use the keys which are given, several oriented vertical and equatorial sections are necessary. It is essential, especially, to have well oriented equatorial sections of specimens of *Helicolepidina* as the

vertical sections of the two recognized species are similar. Therefore, their separation is based on the development of the perie embryonic chambers and the chambers of the spiral whorl.

Key I. - Based mainly on vertical sections

- A. Vertical sections with a trochoid spire around embryonic chambers; peripheral whorls with chamberlet divisions on one or both sides
Helicostegina
 1. Without a pronounced peripheral equatorial layer *Helicostegina dimorpha*
 2. With a pronounced peripheral equatorial layer ..
Helicostegina polygyralis
- B. Vertical sections with a continuous equatorial layer to the embryonic chambers.
 1. Equatorial layer with one or more enlarged chambers indicating position of spiral whorl ..
Helicolepidina
 2. Equatorial layer without enlarged chambers indicating position of the spiral whorl; equatorial chamber walls straight except at their ends *Lepidocyclus* (*Polylepidina*) *antillea*

Key II. - Based mainly on equatorial sections

- A. Vertical sections of *Helicostegina*-type
 1. With a distinct coil of large trochoid chambers before chamberlets develop
Helicostegina dimorpha
 2. With a distinct coil of small trochoid chambers before chamberlets develop
Helicostegina polygyralis
- B. Vertical sections with a continuous equatorial layer
 1. Spiral whorl restricted to area adjacent to embryonic chambers
Lepidocyclus (*Polylepidina*) *antillea*
 2. Spiral whorl extending to the periphery
 - a. Embryonic chambers generating only one perie embryonic chamber which is immediately followed by spiral whorl
Helicolepidina spiralis
 - b. Embryonic chambers generating two perie embryonic chambers; spiral whorl often indistinct in central area
Helicolepidina nortoni

EVOLUTIONARY TRENDS

Before an authoritative statement can be made concerning the derivation of all of the genera of the larger Foraminifera, the characteristics of the various genera must be known fully and their geographic and stratigraphic distribution must be firmly fixed. Although this has not been accomplished as completely as might be desired, it is possible from time to time to suggest prob-

able lineages of descent. It is recognized that as new data become available modifications will be necessary.

Seemingly, *Helicostegina dimorpha* was derived by mutation of an *Amphistegina*-like species. *H. dimorpha* became a well established middle Eocene species which continued into the upper Eocene as *Helicostegina polygyralis*. The genus *Helicolepidina* seemingly was derived from the *Helicostegina* line in the upper middle Eocene. The upper Eocene end species of the *Helicostegina* lineage are *Helicostegina polygyralis* and *Helicolepidina nortoni*.

During the upper middle Eocene the first subgenus, *Polylepidina*, of the genus *Lepidocyclina* was derived also from the *Helicostegina* lineage. However, this lepidocycline lineage immediately became a distinct and expanding one. Seemingly, from *Lepidocyclina antillea* (*Polylepidina antillea*), the only species known to belong to this subgenus, came *Lepidocyclina (Pliolepidina) ariana* Cole and Ponton. This species in turn gave rise to *L. (Pliolepidina) r. douvillei* Lisson, of which *L. (P.) cedarkeysensis* Cole is a synonym, and *L. (P.) peruviana* Cushman. Mutants from these two species established the recognizable species of the upper Eocene which in turn generated the Oligocene and Miocene species.

Gravell and Hanna (1940, p. 416) established the fact that *L. (Pliolepidina) ariana* Cole and Ponton, of which their *L. (Lepidocyclina) claibornensis* is a synonym, occurred stratigraphically above *L. (Polylepidina) antillea* in wells in Mississippi. Later, Cole (1944, p. 34) demonstrated the same stratigraphic relationship in a well in Florida. In this same well *L. (Pliolepidina) r. douvillei* and *L. (Pliolepidina) peruviana* Cushman occur at or near the horizon of *L. (Pliolepidina) ariana*.

This postulated development is similar to the one proposed by Barker and Grimsdale (1936, p. 245) and recently revised by Grimsdale (1959, p. 9). However, Grimsdale argued for a diphyletic origin of the true lepidocyclines. He would relate his "lineage Y" through *L. (Polylepidina) antillea* to the *Helicostegina* lineage, but he stated (1959, p. 11) "The origin of 'Lineage X' cannot yet be identified."

In part he based this conclusion on the fact that the earliest known representative (*L. (Pliolepidina) r. douvillei*) of "Lineage X" is "... found in the middle part of the Middle Eocene (Claiborne equivalent) of eastern Mexico together with *Lepidocyclina antillea*

Cushman, this latter being, of course, the earliest representative of 'Lineage Y' " (Grimsdale, 1959, p. 11).

However, the evidence cited above from Florida and from other Caribbean areas which the writer has studied seemingly is suggestive that *L. (Polylepidina) antillea* is stratigraphically older than any of the other species of *Lepidocyclina*. Moreover, the writer has examined numerous samples from many Caribbean localities which contained *L. (Polylepidina) antillea*. To date, he has never found any other species of *Lepidocyclina* associated with *L. (Polylepidina) antillea*.

Therefore, the true lepidocyclines appear to have originated by mutation from the *Helicostegina* lineage with *L. (Polylepidina) antillea*, the first and most primitive species. All the stratigraphically younger subgenera and species are based upon mutants of *L. (Polylepidina) antillea*.

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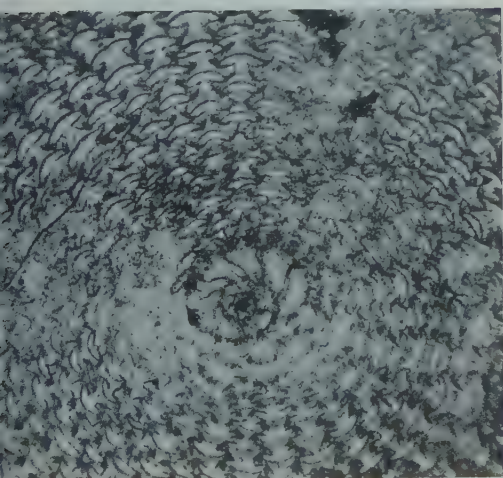
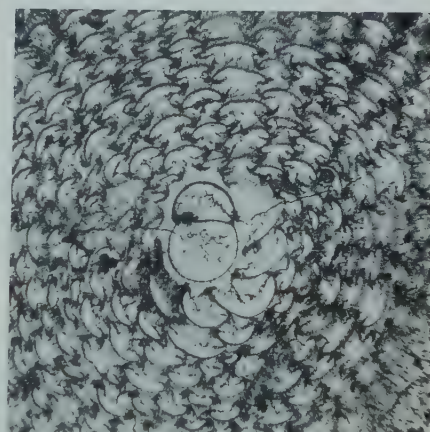
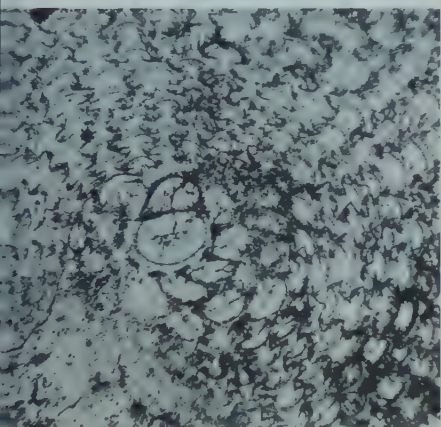
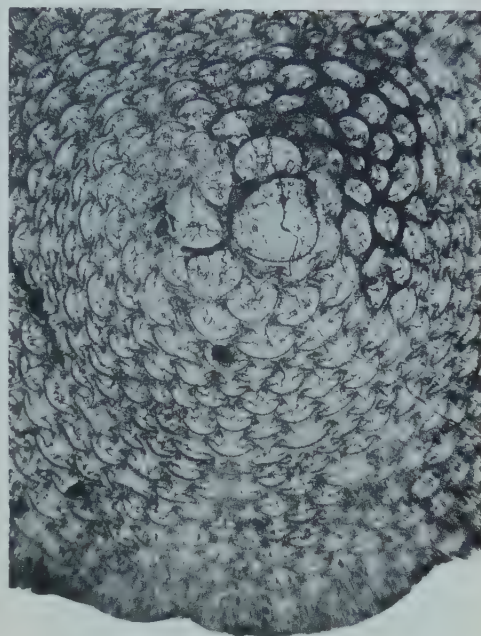
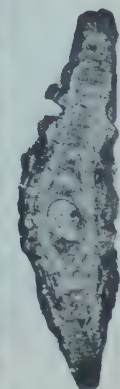
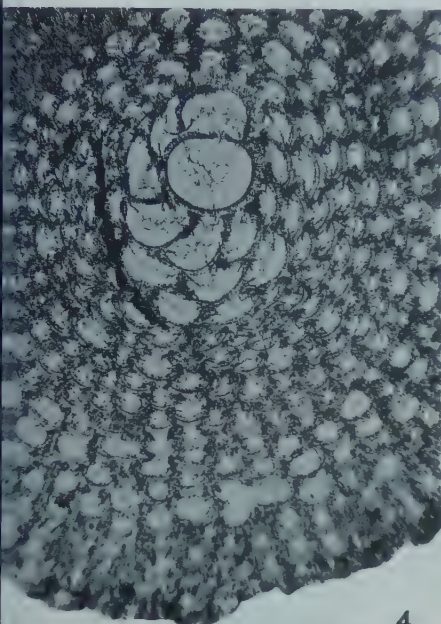
EXPLANATION OF PLATE 12

FIGS.

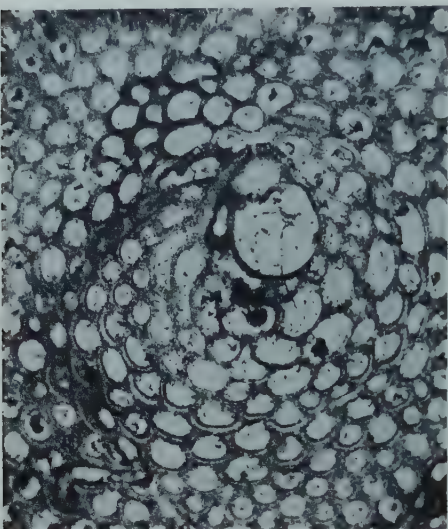
- 1-8. *Lepidocyclina (Polylepidina) antillea* Cushman
- 1, 3, 4, 6, 7. Central part of equatorial sections, $\times 40$, of megalospheric specimens to show the embryonic, periembryonic and equatorial chambers; locality 2a.
 - 2, 5. Vertical sections, $\times 20$, of megalospheric specimens; locality 2a.
 8. Central part of an equatorial section, $\times 40$, of a topotype specimen to show the initial spire of periembryonic chambers and the equatorial chambers; locality 1.

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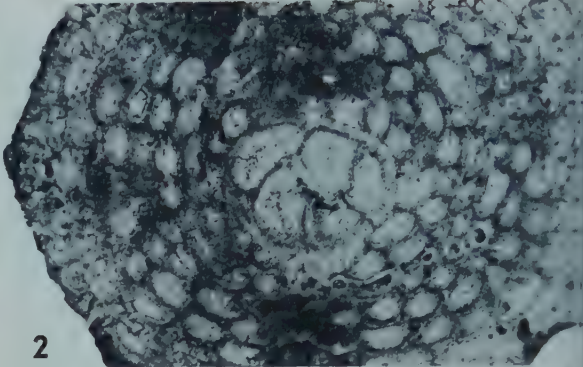
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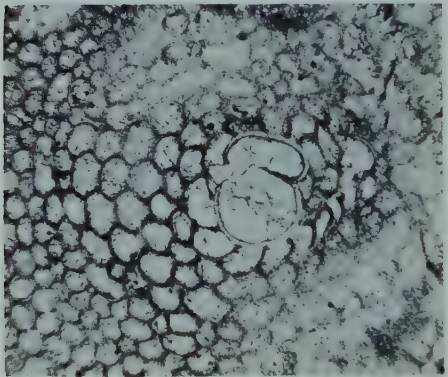
Cole: *Helicostegina*, *Helicolepidina*, *Lepidocyclina* (*Polylepidina*)



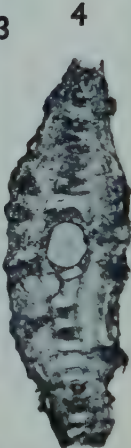
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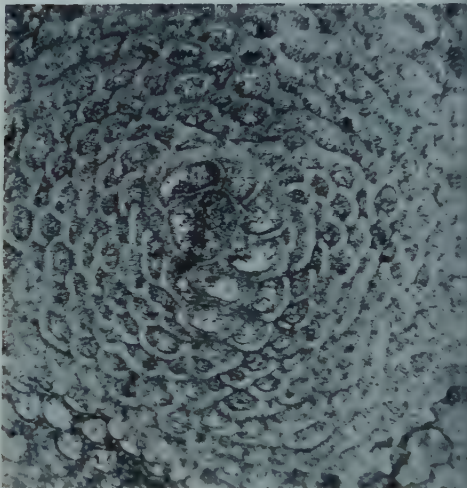
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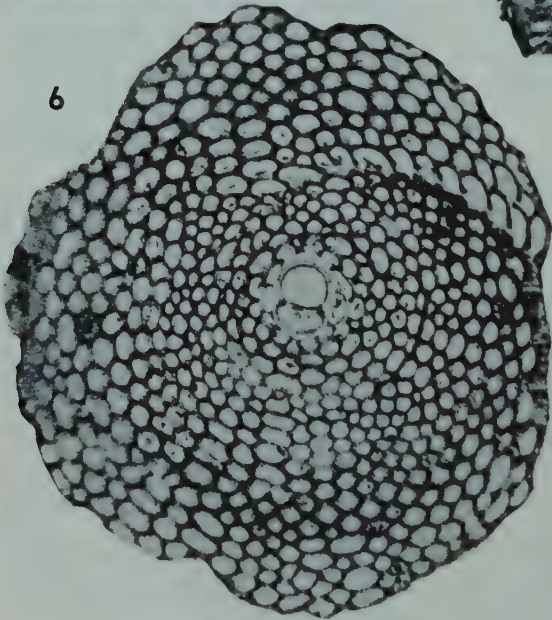
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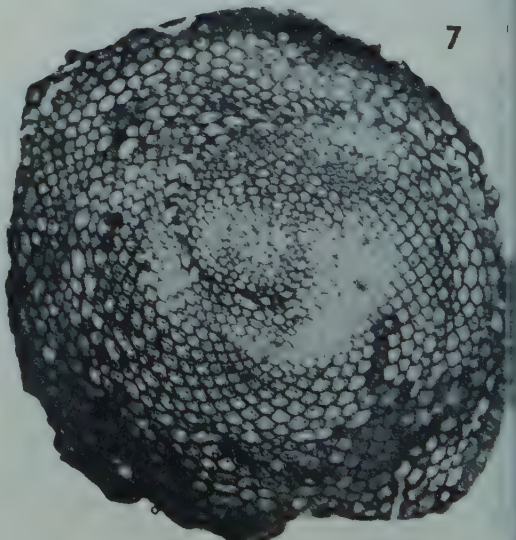
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Cole: *Helicostegina*, *Helicolepidina*, *Lepidocyclina* (*Polylepidina*)

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EXPLANATION OF PLATE 13		
FIGS.		PAGE
1, 2, 4, 5.	<i>Lepidocyclina (Polylepidina) antillea</i> Cushman	60
1, 2, 5.	Central part of equatorial sections, $\times 40$, of megalospheric specimens to show the embryonic, periembryonic and equatorial chambers; 1, 5, locality 2a; 2, locality 2b.	
4.	Vertical section, $\times 20$, of a megalospheric individual; locality 2a.	
3, 6, 7.	<i>Helicolepidina nortoni</i> Vaughan	60
3.	Central part of an equatorial section, $\times 40$, of a megalospheric individual to show the embryonic chambers; locality 3.	
6, 7.	Equatorial sections, 6, $\times 40$, 7, $\times 20$, of megalospheric individuals to show the embryonic and equatorial chambers and the spiral chambers; locality 5.	

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME XI, PART 2, APRIL, 1960

209. SOME OBSERVATIONS
ON ARCTIC PLANKTONIC FORAMINIFERA*

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ABSTRACT

Globigerina pachyderma (Ehrenberg) is believed to be the only species of planktonic Foraminifera living in the present central Arctic Ocean. It is thin-shelled and possesses a large aperture in its early stages (identified as small specimens of *Globigerina eggeri* or *G. bulloides* by previous workers), which contrast with features attained in its mature stages. The typical form of *G. pachyderma*, living below approximately 200 m depth, is attained by crystalline thickening of the test and the addition of a reduced final chamber.

INTRODUCTION

With the establishment in June 1957 of IGY research station Alpha on a drifting ice floe in the Arctic Ocean, the opportunity arose to take plankton tows with the purpose of sampling living planktonic Foraminifera. Since identification of Pleistocene glacial climates is based on the presence of Arctic or Subarctic foraminiferal species in North Atlantic deep-sea cores (Phleger *et al.*, 1953; Ericson and Wollin, 1956), it is desirable to learn how the modern representatives live in Arctic waters. The conclusions reached in this limited study apply primarily to the central Arctic region north of latitude 80° N.

Our knowledge of these organisms is very scanty. Phleger (1952) reported the presence of two species, *Globigerina pachyderma* (Ehrenberg) and *Globigerina bulloides* d'Orbigny, in sediment samples from the Canadian and Greenland Arctic. Ericson and Wollin (1959) have found only *Globigerina pachyderma* in Arctic sediment cores obtained north of Ellesmere Island. Although the planktonic habit of the latter species was inferred (Carsola, 1953) and typical specimens have been reported from plankton tows in Subarctic Pacific waters north of latitude 40° N. (Bradshaw, 1959), these Foraminifera have not been previously studied from plankton-tow samples in the central Arctic Ocean.

METHODS AND MATERIALS

The plankton samples were obtained with a 200-micron mesh size (86 meshes per inch) nylon net, having a 50 cm x 50 cm square face-opening. The net has a nylon cloth collar about 50 cm long, a nylon filtering section 240 cm long, and a cod-end of nylon cloth 10 cm long. The total length of the plankton net is three meters.

For quantitative comparison of plankton samples, an Atlas current meter was attached to the net frame to record the volume of water filtered. Table 1 lists the

collection of Arctic plankton samples upon which this report is based.

A surface sediment sample, collected at Station Alpha on June 15, 1958, at Lat. 84° 23' N and Long. 148° 51' W, provided direct comparison between foraminiferal tests from plankton samples taken in near-surface waters and those deposited directly beneath on the ocean floor.

ACKNOWLEDGMENTS

The collection of plankton samples on Drifting Station Alpha and their laboratory analysis were made possible through grants from the Arctic Institute of North America (AINA - 47), Air Force Cambridge Research Center (AF 19(604)-2030), and the National Science Foundation (G-9557) to the Lamont Geological Observatory.

Dr. Kenneth Hunkins and Mr. Henry Flemming of the Lamont Geological Observatory collected the samples during the summer and fall of 1958.

SYSTEMATIC DISCUSSION

Only one form of planktonic Foraminifera was consistently encountered in the 36 plankton-tow samples from the central Arctic Ocean (Fig. 1C). Its small size (150-300 microns) and lack of diagnostic features made taxonomic identification difficult. It most resembled the juvenile stages of *Globigerina eggeri* Rhumbler or *Globigerina bulloides* d'Orbigny, and it appeared to be identical to the specimen illustrated and listed as *Globigerina bulloides* by Phleger (1952, plate 14, figs. 27-28). He stated that *Globigerina pachyderma* and *G. bulloides* were the only two recognizable species of planktonic Foraminifera in the Canadian and Greenland Arctic seas. The former was the most abundant form encountered in his sediment samples. However, the Arctic form in the present plankton samples does not resemble the typical form of *Globigerina bulloides* commonly present in the North Atlantic south of Greenland, nor the typical form of *G. pachyderma*. Typical *G. bulloides* has a larger umbilical aperture, more globular final chamber, generally has four chambers constituting the last whorl, is larger in size and has a predominantly left-coiling direction. The Arctic form shown by Phleger and the form consistently found in the present plankton-tow samples are more compact, have smaller apertures and have four to five chambers in the last whorl with a predominantly left-coiling direction also.

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TABLE 1. Plankton Samples Collected on Drifting Station *Alpha*

Sample No.	Date	LOCATION		Depth of tow (m)	Vol. of water filtered (m ³)	Total time of tow (min.)	Surf. temp. (C°)	Total living Forami- nifera in sample	No. of Forami- nifera per 1000 m ³ (larger than 200 μ)
		Lat. N.	Long. W						
1958									
2	4-24	83-57	151-53	0-300	.....	.....	almost constant at -1.7° C	1	.....
4	4-24	83-57	151-53	0-100	.....	.....		1	.....
5	6-18	84-33	147-42	0-500	.....	.....		1	.....
7	6-18	84-33	147-42	0-200	.....	.....		2	.....
I	6-23	84-35	147-37	0-50	0.9	1090		7	.....
II	6-24	84-38	147-33	0-80	0.9	1345		3	.....
III	6-25	84-37	147-34	0-400	2	1290		4	.....
IV	6-27	85-33	147-48	0-1003	3	1330		3	.....
V	7-8	84-32	146-05	0-6	233	30		147	291
1	9-24	85-48	120-29	0-10	7.7	181		1	0
2	9-25	85-48	120-29	0-20	4.3	300		6	464
3	9-25	85-48	120-29	0-75	11.1	883		19	270
4	9-26	85-49	119-45	0-100	101.2	1441		17	90
5	9-29	85-46	120-30	0-120	100.1	575		9	20
6	9-29	85-46	120-30	0-60	23.8	805		3	42
7	9-30	85-46	120-30	0-30	9.4	582		6	106
8	10-1	85-46	120-30	0-40	16.2	365		3	124
9	10-2	85-38	120-40	0-50	12.8	385		3	78
10	10-3	85-40	120-31	0-150	17.0	412		0	0
11	10-4	85-41	119-55	0-90	103.5	820		6	10
12	10-4	85-41	119-55	0-200	151.3	360		10	28
13	10-5	85-44	120-10	0-110	392.9	2250		15	8
14	10-7	85-53	120-25	0-130	16.7	910		10	60
15	10-10	85-58	119-29	0-130	15.1	365		0	0
16	10-11	85-58	119-29	0-30	13.6	1085		4	74
17	10-11	85-58	119-29	0-10	93.0	1070		6	33
18	10-12	85-58	119-29	0-190	125.0	524		2	0
19	10-12	85-58	119-29	0-170	123.0	513		7	16
20	10-12	85-58	119-29	0-180	33.1	452		2	30
21	10-12	85-58	119-29	0-160	33.5	440		1	30
22	10-13	85-59	119-29	0-40	93.8	717		1	0
23	10-13	85-59	119-29	0-20	79.8	717		0	0
24	10-13	85-59	119-29	0-70	18.9	310		0	0
25	10-13	85-59	119-29	0-50	16.2	275		2	63
26	10-14	86-02	119-30	0-80	25.7	2385		0	0
27	10-14	86-02	119-30	0-60	19.4	2372		7	50

Two questions arose during examination of the present plankton samples. First, why was *Globigerina pachyderma* apparently absent in near-surface Arctic waters, although it is normally the most typical and abundant Arctic species of planktonic Foraminifera in the bottom sediments? Second, to what species does the form in the plankton-tow samples belong?

After examination and comparison of foraminiferal tests in bottom sediments and plankton-tow samples, the writer has come to the conclusion that only one species of planktonic Foraminifera is living in the mod-

ern central Arctic seas, *Globigerina pachyderma*, and that the form in the plankton samples is an early-stage (not necessarily juvenile) morphological variant of this species. This view was reached after studying the ontogenetic development of typical tests of *G. pachyderma*. It was found upon breaking off the final chamber of numerous tests of typical *G. pachyderma* (Fig. 1A) from Arctic bottom sediments that the earlier developmental stages (Fig. 1B) revealed a form remarkably similar to small "*G. bulloides*" and "*G. eggeri*." More significantly, the latter (Fig. 1B) was identical

to the form present in plankton-tow samples (Fig. 1C).

Thus, *G. pachyderma* is typical when its final chamber is reduced in size and has a constricted aperture. Without this kind of final chamber its diagnostic features are not apparent and it then resembles small forms of *G. bulloides* and *G. eggeri*.

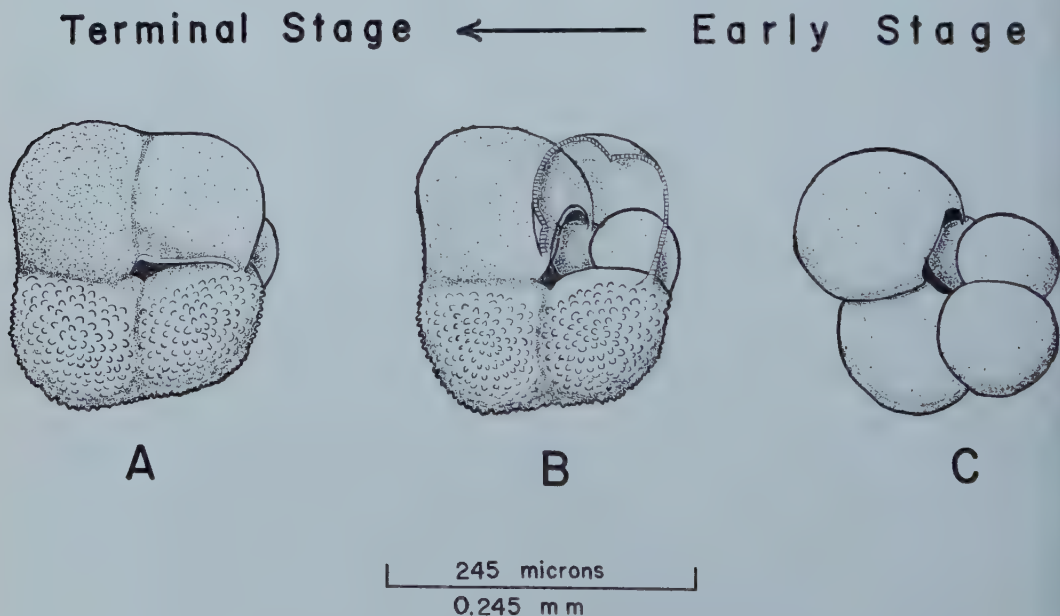
Early-stage of *G. pachyderma*, confused by many authors as *G. bulloides* and/or small *G. eggeri* (Fig. 1B):

1. Predominantly present in near-surface water (0-200 m). Less common in bottom sediments.
2. Four to four and one-half chambers in last whorl — the later ones becoming progressively larger.
3. Spherical chambers distinct.
4. Final chamber larger than earlier chambers.
5. Relatively large aperture extending from umbilicus to periphery. No prominent apertural ridge.
6. Left-coiling direction generally.
7. Average size — 250 microns along maximum dimension.

The following comparisons are tabulated between (a) the typical, terminal form of *G. pachyderma* present predominantly in the bottom sediments, and (b) the juvenile form found living in near-surface waters or revealed by breaking off the final chambers of typical tests of *G. pachyderma* in bottom sediments.

Typical final-stage of *G. pachyderma* (Fig. 1-A):

1. Predominantly present in bottom sediments (as empty tests); rarely living in near-surface waters, more common in tows deeper than 200 m.
2. Four to four and one-half chambers in last whorl — subequal in size due to crystalline thickening of earlier chambers and relatively small size of final chamber.
3. Chambers appear to coalesce due to crystalline thickening of test.
4. Final chamber equal in size or smaller than penultimate chamber.
5. Constricted aperture with prominent apertural ridge, directed to umbilicus.
6. Left-coiling direction generally.
7. Average size — 250 microns along maximum dimension.
8. Important: When the final chamber is removed the earlier chambers reveal a form (Fig. 1B) identical to the early-stage *G. pachyderma* similar to *G. bulloides* and *G. eggeri*.



TEXT FIGURE 1

Morphological variations in the ontogeny of *Globigerina pachyderma* (Ehrenberg). A, typical final-stage specimen from Arctic bottom sediments; B, same specimen with final chamber broken off; C, modern specimen in early developmental stage from plankton-tow sample. Note the thickened test of A and B and the similarity between B and C.

The interpretation that there is an ontogenetic relationship between these two forms would explain and solve some taxonomic problems among Arctic planktonic Foraminifera. First, because the early-stage form is so unlike the typical form of *G. pachyderma*, the former was generally identified as small specimens of *G. bulloides* and/or *G. eggeri* by earlier investigators (e.g. Phleger, 1952, Bradshaw 1959, pp. 35-36; and Bé 1959, p. 84). However, typical forms of *G. bulloides* or *G. eggeri* are not found in Arctic bottom sediments. Second, since final-stage *G. pachyderma* has not been commonly observed in plankton-tow samples, its planktonic habit was not firmly established (Brady 1884; Cushman and Henbest 1940; Carsola 1953). Bradshaw (1959), however, has identified typical *G. pachyderma* from plankton tows taken in Subarctic Pacific waters north of latitude 40° N. The present interpretation is that *G. pachyderma* does appear in near-surface Arctic waters, but that in its early developmental stage it appears significantly different in morphology from the typical form in the bottom sediments. Third, the predominance of early stage *G. pachyderma* and the virtual absence of final-stage *G. pachyderma* in near-surface waters contrasts with the reverse quantitative relationship in the bottom sediments of the Arctic Ocean. This is interpreted as a consequence of transformation of early-stage *G. pachyderma* to final-stage *G. pachyderma* at relatively deep depths (greater than 200 m). The morphological changes are in the addition of a reduced final chamber (which constricts the aperture) and in the crystalline thickening of the test.

It is of interest to note that the crystalline thickening of the test is done organically and not post-depositionally by inorganic agents on the ocean floor. Proof of the former lies in the pores that penetrate the thickened portion of the test and the fact that selected parts (especially the first two chambers in the last whorl) of the test are thickened. Inorganic coating would be uniform and less selective. The ability of planktonic Foraminifera to add calcium carbonate at various depths and, consequently, at various temperatures must be taken into consideration in paleotemperature studies using the oxygen-isotope method (Emiliani, 1955). When the latter method is applied to interpret depth habitats of species of planktonic Foraminifera, it can at best indicate the mean, optimum depth preferred by a species. The space-time dimensions a given species occupies are extensive and complex. The planktonic Foraminifera spend their early stages in the euphotic zone, presumably since they feed upon plants and perhaps because of presence of symbiotic algae. There is good evidence that some species can live at great depths and, in the process of descending, add calcium carbonate to their tests. It is not clear, however, what the functions of such descent

and structural modification are and how this relates to the life cycle of the individual foraminifer.

STANDING CROP

Measurements of the concentration of the only species of planktonic Foraminifera in the Arctic waters, *G. pachyderma*, are listed in Table 1. These are not considered wholly accurate, but are useful for comparison of relative abundance. The standing crop figures are influenced by two artificial factors. First, the rate of water flow into the plankton net was so low that the propeller of the current meter may not have been revolving properly. Consequently, the calculated figures for the volume of water filtered would be too low on the average and, therefore, the resulting calculations for the abundance of Foraminifera per standard volume of water would be too high. Second, the relatively coarse (200-micron diameter) mesh size of the net probably allowed a large portion of small *G. pachyderma* to pass through the net. This would result in standing crop calculations that are too low.

If the standing crop figures given in Table 1 are primarily used for comparison of relative abundance, the indications are that planktonic Foraminifera were more abundant in the summer (June) than in the fall (September and October). Their concentration decreased gradually from September 24 to October 14, 1958.

The use of the standard net with 200-micron diameter mesh allowed direct comparison of foraminiferal standing crops of the same size range in the Arctic Ocean and the temperate and equatorial regions of the Atlantic Ocean. The comparative standing crops of planktonic Foraminifera in the Arctic Ocean, the temperate North Atlantic (Bé, 1959) and the Caribbean Sea (Bé, unpublished data) are as follows:

	Number of Species	Average no of Specimens per 1000 m ³ of water
Arctic region	1	67
W. North Atlantic	16	3400
Caribbean Sea	17	7650

The geologic significance of planktonic Foraminifera lies in their important contribution as organic constituents of bottom sediments. By determining their productivity and mortality rate, it is possible to evaluate the rate of sedimentation of foraminiferal tests. Although the standing crop values shown above represent limited periods of observation, it may be inferred that the rate of organic sedimentation is greatest in the warmer seas and decreases toward the Arctic region. Since the subtropical species are also larger in size on the average than the Arctic species, there is a correspondingly greater amount of calcium carbonate being deposited in the subtropical regions as compared with the Arctic.

It is also of interest to note that there is only a single species (*G. pachyderma*) living in the central

Arctic waters, whereas there are 16 and 17 species in the western North Atlantic and Caribbean Sea, respectively. This is of significance since the proportion of cold-to warm-tolerant species is a useful criterion for determining relative temperatures of near-surface waters in which the foraminiferal species originally lived.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XI, PART 2, APRIL, 1960
RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

- ALEXANDROWICZ, STEFAN. Les sédiments du Crétacé supérieur à Nowa Cerekwia près de Glubczyce (in Polish with French summary).—Ann. Soc. Géol. Pologne, Krakow, tom 29, fasc. 2, 1959, p. 165-179, pls. 13-15 text figs. 1-3 (map, section, graph, range chart), table 1.—Illustrations of 19 species of Coniacian age.
- Age of transgressive Miocene deposits at Mazanowice near Bielsko (western Carpathians) (English summary of Polish text).—Poland Instyt. Geol., tom 3, No. 3, 1959, p. 662-676, text fig. 1 (section), tables 1, 2.—Many small Foraminifera listed. Tortonian age indicated.
- ANSARY, S. E., and FAKHR, BOSSAYNA Y. Maestrichtian Foraminifera from Um El Huetat area, west of Safaga.—Egyptian Jour. Geology, v. 2, No. 2, 1958, p. 105-146, pls. 1, 2, text fig. 1 (columnar section), correl. table.—Forty-seven species, subspecies, and varieties; one species new.
- ASCOLI, PIERO. Studio micropaleontologico preliminare sulla posizione stratigrafica della cosiddetta "Pietra da Cantoni" nel Tortonese.—Boll. Soc. Geol. Ital., v. 77, fasc. 1, 1958 (1959), p. 11-25, table.—Numerous Helvetian species listed.
- ASHWORTH, EDWIN T. Occurrence of *Globotruncana ventricosa* in northwestern Peru.—Micropaleontology, v. 5, No. 4, Oct. 1959, p. 497-499, text figs. 1 (map), 2 (drawings).—In cores of Maestrichtian age.
- AVES, CHARLES. Foraminiferal fixatives and preservatives.—Gulf Coast Assoc. Geol. Soc., Field Trip Guidebook Sedimentology of South Texas, Oct. 30-Nov. 1, 1958, p. 62-70, table 1.—Use of anesthetic prior to addition of preservative increases ease of recognizing living specimens by causing some of the protoplasm to remain outside the shell.
- BACH, HANS, HAGENMEYER, PETER, and NEUWEILER, FRITZ. Neubeschreibung und Revision einiger Foraminiferenarten und -unterarten aus dem schwäbischen Lias.—Geol. Jahrb., Band 76, Oct. 1959, p. 427-451, pls. 21, 22, text figs. 1, 2.—Eight new species and 5 given new names. One new subspecies and 2 more given new names.
- BARTENSTEIN, HELMUT. Die Barrême-Scholle von Mellendorf nördlich Hannover, ehemaliger locus typicus von Roemer 1841, Müller 1893 und Koenen 1902.—Geol. Jahrb., Band 76, Oct. 1959, p. 453-467, pls. 23, 24, text figs. 1-5 (maps, sections).—Photographs of Lower Cretaceous assemblages.
- BEDDOES, LESLIE R., JR. Foraminiferal populations of the Goodland formation, Tarrant County, Texas.—Field & Laboratory, Southern Methodist Univ., Dallas, v. 27, No. 2, April 1959, p. 51-70, text figs. 1-5 (maps, section, chart, drawings), tables 1, 2.—Quantitative study involving about 80 species, more than 14 indeterminate, and interpretation of paleoecology.
- BIEDA, FRANCISZEK. Nummulites of the Magura series (Polish Western Carpathians) (English summary of Polish text).—Poland Instyt. Geol. (Warsaw), Biul. 131, v. 2, 1959, p. 5-37, pls. 1, 2, tables 1, 2.—Four zones are recognized. A few species are illustrated.
- BIEDA, FRANCISZEK, and KSIAZKIEWICZ, MARIAN. On the age of the Babia Gora sandstone (English summary of Polish text).—Poland Instyt. Geol., tom 2, No. 4, 1958, p. 841-856, pl. 1.—Nummulites, listed and illustrated, indicate Lutetian age.
- BIELECKA, WANDA, and PAZDRO, OLGA. On the apparent stratigraphical unconformity between micro- and macrofauna (in Polish).—Przegląd Geol., No. 10, 1959, p. 450-453, text figs. 1-4 (diagrams).
- BLASZYK, JANUSZ. Foraminifers of the Middle Bononian from Brzostowka near Tomaszow Mazowiecki (central Poland) (English summary of Polish text).—Poland Instyt. Geol., tom 3, No. 3, 1959, p. 713-720, text figs. 1, 2 (map, range and abundance table).
- BOLTOVSKOY, ESTEBAN. Foraminifera as biological indicators in the study of ocean currents.—Micropaleontology, v. 5, No. 4, Oct. 1959, p. 473-481, pls. 1-3, text fig. 1 (map).—North-flowing Malvin current recognized, and distinguished from the south-flowing Brazilian current and from the Argentinian coastal waters, by its planktonic species and the benthonic species on the ocean floor over which it flows.
- BRAMLETTE, M. N., FAUGHN, J. L., and HURLEY, R. J. Anomalous sediment deposition on the flank of Eniwetok Atoll.—Bull. Geol. Soc. Amer., v. 70, No. 12, pt. 1, Dec. 1959, p. 1549-1551, text fig. 1 (map).—Short cores from a deep shelf adjoining the atoll reveal a thin and discontinuous veneer of non-indurated Quaternary sediment (mostly reef debris) on late Tertiary material that is finer grained and slightly indurated. Agitated water at 800- to 1000-fathoms depth is indicated for present conditions but was lacking in late Tertiary under comparable topographic relations. *Globigerinoides sacculifera fistulosa* (Schubert) is suggested as possibly an indicator of Pliocene age.
- BROTZEN, F., and DINESEN, A. On the stratigraphy of some bottom sections from the Central Pacific.—Reports Swedish Deep-Sea Expedition 1947-1948, v. X, Special Investigations, fasc. III, June 1959, p. 43-55, text figs. 1-4 (graphs).—Correlation between cores by means of 7 alternating maxima and minima of specimens of *Globigerina*. The phenomenon of substitution of *Globigerina* and *Globorotalia* was observed (that is, maximum of one coincides with minimum of the other).
- BYKOVA, N. K. Materialy K Paleohkologii Foraminifer Alajskogo i Turkestanskogo Jarusov Paleogena Ferganskoy Doliny.—Russia Vses. nef. nauchno-issl. geol.-inst., Trudy, vyp. 136, Mikrofauna SSSR, Sbornik 10, 1959, p. 544-613, pls. 1-5, text figs. 1-4.—Twelve species (10 new) and 2 new varieties.
- CATI, FRANCO. Nuovo Lituolide nei Calcari grigi Liasici del Vicentino.—Giornale Geol., Ann. Mus. Geol. Bologna, ser. 2, v. 27, 1956 (1959), p. 1-10, pl. 1, text figs. 1, 2.—*Lituosepta recoarensis* n. gen. n. sp., having secondary and transverse septa.
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11. August 1959, p. 81-90, pls. 1-3, text fig. 1 (map).—Sixteen species and subspecies.
- CITA, M. B., and RUSCELLI, M. A. Cretaceous microfossils from western Pakistan and Afghanistan.—*Riv. Ital. Pal. Stratig.*, v. 65, No. 3, 1959, p. 231-252, pls. 8-13, text fig. 1 (map).—Several Lower and Upper Cretaceous Foraminifera associations illustrated in thin section.
- CRESPIN, IRENE. Microfossils in Australian and New Guinea stratigraphy.—*Journ. Proc. Royal Soc. New South Wales*, v. 92, 1958 (Sept. 30, 1959), p. 133-147.—Includes historical review and bibliography.
- DIDKOVSKIY, V. J. Sur un nouveau représentant de la famille des Miliolidae: *Tortonella bondartschuki* gen. et sp. nov. du Tortonien d'Ukraine (French translation from Russian).—*Doklady Akad. Nauk SSSR*, tom 113, No. 5, 1957, p. 1137-1139, text figs. 1-3.
- DIECI, G. I foraminiferi tortoniani di Montegibbio e Castelvetro (Appennino Modenese).—*Palaeontographia Italica*, v. 54 (n. ser. v. 24), Anno 1959, p. 1-113, pls. 1-8, text figs. 1, 2 (graphs).—Illustrated catalog of 209 species and subspecies; 5 are new. The Castelvetro material was laid down under deeper conditions than that of Montegibbio.
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- DROOGER, C. W., and SOCIN, C. Miocene Foraminifera from Rosignano, northern Italy.—*Micropaleontology*, v. 5, No. 4, Oct. 1959, p. 415-426, pls. 1, 2, text fig. 1 (map), tables 1, 2.—Two species of larger Foraminifera and associated smaller Foraminifera of Burdigalian age.
- DUFAURE, PH. Problèmes stratigraphiques dans le Crétacé Supérieur des Pays de Bigorre et de Comminges.—*Revue de Micropaléontologie*, v. 2, No. 2, Sept. 1959, p. 99-112, pls. 1-3, map, table 1.—Foraminifera illustrated in section.
- DURKINA, A. V. Foraminifery Nizhnekamennougol'nykh Otlozhenii Timano-Pechorskoj Provinthii.—*Russia Vses. neft. nauchno-issl. geol.-inst.*, Trudy, vyp. 136, Mikrofauna SSSR, Sbornik 10, 1959, p. 132-339, pls. 1-27, text figs. 1-7, tables 1-3.—One hundred twenty-three species and varieties (79 species and 9 varieties new), mostly endothyrids and related genera.
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- DI NAPOLI ALLIATA, ENRICO. Étude de la carotte No. 19 campagne du "Vema" dans la Méditerranée (Mer Tyrrhénienne), in La Topographie et la Géologie des Profondeurs Océaniques.—Colloques Internat. du Centre Nat. Recherche Sci., Nice-Villefranche 5-12 Mai 1958, 1959, p. 61-71, table.—Analysis of a 2.9 meter core indicates age to be Pleistocene (end of Tyrrhenian). Planktonic and benthonic species are listed. Foraminiferal molds are found in glauconite layers in the core.
- OKROPIRIZDE, D. V. Au sujet des loges complémentaires des Globigerines (French translation from Russian).—Doklady Akad. Nauk SSSR, tom 106, No. 2, 1956, p. 338-341, text figs. 1-4.—Supplementary chambers, found mostly in globigerinids (but one is illustrated in *Nonion*), may be a result of some disturbance of the normal course of development. Such disturbance could result from the absence of certain environmental conditions indispensable for the passage of an adult organism into the reproductive stage. The animal continues to live, metabolism continues but with less intensity and regularity, and chambers are added but they will be abnormal ones (small, thin-walled, smooth) because the skeleton has completed its growth.
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- However, sand layers at top and near the bottom of the core, of allochthonous origin, contain planktonic Foraminifera and a mischfauna of benthonic species from various shallower depths, suggesting more than one displacement or mixing during displacement. Specimens show various degrees of solution effects or fragmentation, probably related to rapidity of burial. *Fissurina* is placed under *Oolina* as a subgenus, requiring a new name, *F. parri*, for its type species, *F. laevigata* Reuss. One new subspecies is erected.
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